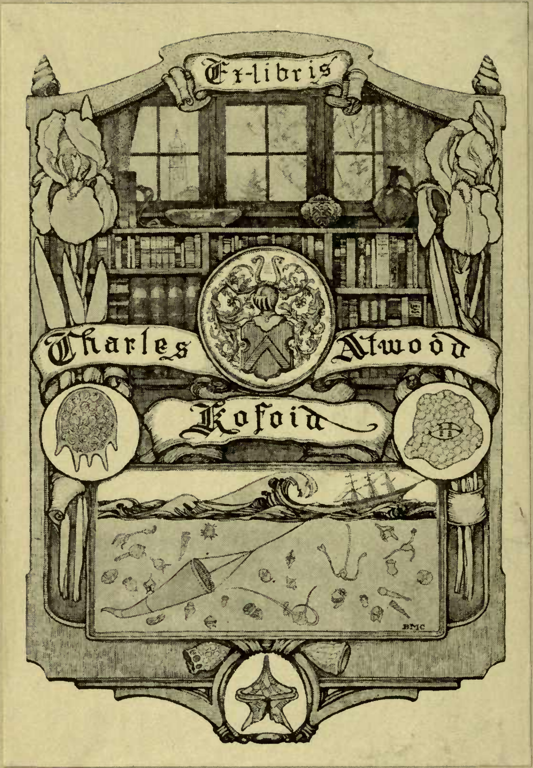
Ex-libris
Charles Atwood
Kofoid
BMC

A

SURVEY

OF THE

WISDOM OF GOD

IN THE

CREATION:

OR,

A COMPENDIUM

OF

Natural Philosophy.

IN FIVE VOLUMES.

By JOHN WESLEY, A. M.

A NEW EDITION, REVISED AND CORRECTED.

VOL. IV.

These are thy glorious Works, Parent of Good,
Almighty! Thine this universal Frame,
Thus wondrous fair! Thyself how wondrous then!
MILTON.

LONDON:
Printed by J. D. Dewick, 46, Barbican,
FOR MAXWELL AND WILSON, 17, SKINNER-STREET, SNOW-HILL;
AND WILLIAMS AND SMITH, STATIONERS'-COURT.

1809.

CONTENTS

OF THE

FOURTH VOLUME.

PART the FIFTH.

[CONTINUED.]

CHAP. III.

Of the Properties that are common to all Bodies.

CHAP. IV.

Of those Things wherein Natural Bodies differ.

CHAP. II.

Of the relative Perfection of Beings.

CHAP. III.

General View of the gradual Progression of Beings.

CHAP. IV.

Continuation of the gradual Progression of Beings.

CHAP. V.

Of the various Relations of Terrestrial Beings.

CHAP. VI.

Of Vegetable Economy.

CHAP. VII.

Of Animal Œconomy.

CHAP. VIII.

Of Animal Economy, considered in Insects.

CHAP. IX.

Continuation of Animal Economy considered in Insects.

CHAP. X.

Parallel between Plants and Animals:

CHAP XI.

Of the Industry of Animals.

CHAP. XII.

Continuation of the Industry of Animals.

A

COMPENDIUM

OF

NATURAL PHILOSOPHY.

PART THE FIFTH.

CHAP. III.

Of the Properties that are common to all Bodies, and of the Elements of Natural Bodies.

1. HAVING spoken of the particular species of bodies, it remains only to speak of bodies in general: and it may be observed of them all, that they are extended, solid, divisible, figured, and capable of motion. We cannot conceive any body that is not *extended* or composed of several parts: and yet we cannot affirm that the *essence* of body consists in this alone.

2. For there may be extension without body, which is usually termed *space* or a *vacuum*: these are widely different from each other. Body is divisible and separable into parts, and consequently capable of motion; none of which can be said of mere space: and that there is empty space is clear from hence:—that if all were full, there could be no motion in the world; for in order to this, it is requisite that each particle leave its place empty for another to fill. It is said, indeed, this need not be, because all motion is circular, so that in every motion, of whatever kind, each part of the body moved succeeds another. But this is absolutely contrary to matter of fact: we see with our eyes that all motion is not circular; and if not, then there must be empty space, or there could be no motion at all.

3. Another property of body is *solidity*, whereby it resists another body, moving it out of its place. Not much different from this is *impenetrability*, whereby a body excludes another from the place where it is. Solidity is not the same with *hardness*, the former belonging to all, the latter to some bodies only. Hardness consists in the firm cohesion of the parts, so as not easily to be separated. As the solidity of bodies flows from the intrinsic nature of matter, it is vain to assign as the cause of it, either the figure or rest of the parts, or the pressure of the air, or of some subtle matter. By these solutions we do not at all explain the thing, but only entangle ourselves in fresh difficulties.

4. *Divisibility* likewise belongs to all bodies; for since no body can be conceived that is not extended, and extension supposes parts, it follows, that every body, however small, is divisible: perhaps not by the art of man, but in its own nature. Nor is it any objection that our understanding cannot comprehend *infinite divisibility*—it cannot; nor can it comprehend infinite number, or, indeed infinites of any kind.

It is true there is no such thing, strictly speaking, as parts infinitely small; yet the smallness of the particles of several bodies, is such as vastly surpasses our conception. And there are innumerable instances in nature of such parts actually separated from each other.

Mr. Boyle gives us several instances of this: he speaks of a silken thread three hundred yards long, that weighed but two grains and a half. Fifty square inches of leaf-gold weighed but one grain. Now if the length of an inch be divided into two hundred parts, the eye may distinguish them all; therefore, there are, in one square inch, forty thousand visible parts; and, in one grain of leaf-gold, two millions of such parts: which visible parts no one will deny to be farther divisible. In odoriferous bodies, we may discern a still greater subtlety of parts, yea, of parts actually separated from each other. Several bodies scarce lose any thing of their weight in a long time, and yet continually fill a large space with odoriferous particles. Several animals are but just visible with the finest microscope: and yet these have all the parts necessary for life, as blood and other juices. How wonderful must the subtlety of the parts be whereof those fluids are composed: and hence the following strange theorem is deduced and demonstrated by Dr. Keil.—"Any particle of matter, how small soever, and any infinite space, how large soever, being given, it is possible for that particle to be diffused through all that space, and to fill it in such a manner that there shall be no pore in it whose diameter shall exceed any given line."

5. The last general property of matter is *motion* and *rest*; for it is plain all matter is either at rest or in motion. God is the first and universal cause of motion, as well as of all these things: the immediate cause of it is either matter or spirit. It is beyond doubt, that a body moved communicates its motion to another, though in its own nature it be purely passive. Nor

can we reasonably deny that a spirit is able to move matter, although the manner of its doing this we cannot comprehend.

6. All the laws of motion may be reduced to three: 1. Every moving body is moved by another. 2. Every moving body communicates its motion to any body it meets. 3. Every moving body continues in motion till it communicates that motion to another. While these laws remain in force, and concur in producing various effects, those effects are termed natural. When any of these laws are suspended, this is properly a miracle.

7. As the elements or first stamina of bodies are too small to be discerned by any of our senses, we can only form conjectures concerning them. The most probable conjectures are these: Empedocles, and Aristotle, from him, supposed there are four elements, *fire, air, water* and *earth*: and, indeed, this division seems to be grounded on the nature of things; for there is no doubt but at the creation of this globe the confused mass was separated into four parts, the heaviest of which constituted the *earth*, the particles next in weight the *water*, the third, lighter still, *air*, and the lightest of all, *fire*, otherwise termed *ether*. And it is manifest, all bodies known to us are reducible to one or more of these. Every thing corporeal is either earth, air, water or fire, or compounded of them. So that after all the disquisitions of two or three thousand years, this easy, plain, natural account of the elements, is not likely to be amended: it being a certain fact that of these do all bodies consist.

8. The chymists have taken another way, endeavouring to trace the principle of bodies, not by the ordinary use of their senses, nor by reasoning, but from experiments made by fire: and by this means they make five elements; for whatever is distilled first emits a sapid and spiritous vapour, which is by cold con-

denced into a liquor: and this they term *mercury*: then an insipid liquor, which they call *phlegm*: afterward an acid liquor, which is also termed *mercury*. A thicker and oily liquor comes next, which, because easily inflammable, is stiled *sulphur*. The *salt*, which is afterwards found, is their fourth element, the insipid *earth*, which is left, the fifth.

9. But not to insist, that all bodies are not resolvible into these principles, it is utterly uncertain whether fire does not alter the natural qualities of bodies, and introduce other qualities into them, which they had not before: besides, some of these are not simple elements, they are compounded of others, oils, and salts in particular: therefore, neither are all those oils and salts of one sort, but as various as the bodies from which they are extracted. In truth, these are at most the constituent parts of two of the Aristotelic elements, namely, water and earth; but the two others, air and fire, are quite omitted in their account.

10. Perhaps one might rather term *matter* itself, with its general properties, the first and most simple element, out of which all things are compounded: but the particles of this are not fit to compose the immediate stamina of larger bodies, till they combine together into oils, salts, and juices of various kinds. And hence arise those principles of the chymists, of which most bodies are compounded, although still they are only secondary elements, as being themselves compounded. Indeed, it seems probable, God, in the beginning, formed matter in solid, impenetrable, moveable particles, of such sizes and figures as most conduced to the end for which he formed them; and that these primitive bodies are incomparably harder than any porous bodies compounded of them, even so hard as never to wear out, no natural power being able to divide them: and thus remaining entire, they compose bodies of the same nature and texture in all ages; whereas, should these wear away, or break in

pieces, the nature of things depending on them would be changed. Nor would water and earth, composed of broken worn-out particles, be the same as they were at the beginning: but they are the same in all ages; and the changes of things do not imply any change in those original particles, but only various associations and separations of them; nor do compound bodies ever break in the middle of solid particles, but where those particles are joined together, and only touch in a few points.

CHAP. IV.

Of those Things wherein Natural Bodies differ.

---

1. HAVING considered wherein natural bodies agree, we come now to consider the particular properties wherein they disagree, and whereby they are distinguished from each other: those of them which are perceived by our outward senses, are divided accordingly into various classes, as they affect the sense of sight, of hearing, of tasting, of smelling, or of feeling.

2. *Light* seems to be one of the most subtle bodies in the universe: the grand reservoir thereof is the sun; but it is likewise emitted by many other bodies, and by almost all when they are on fire. When it falls on any body which it cannot pass through, and so is beat back, it is said to be *reflected*: but when it passes from one *transparent* body into another, which is either rarer or denser, it moves obliquely, its rays being bent, and is said to be *refracted*: when it passes through a body in strait lines, it is said to be *transmitted*. Those which emit the light are termed *lucid* bodies,—those which reflect it, *opake*.

The particles of light, minute as they are, are attracted by those of other bodies: hence, in their passage near the edges of bodies, whether opake or transparent, they are diverted from the right lines, and reflected towards those bodies. This action of bodies on light exerts itself at some distance, but increases as the distance is diminished, as appears in the passage of a ray between the edges of two thin plates, at different apertures, in which it is peculiar, that the attraction of one edge is increased as the other is brought nearer it. The rays of light passing out of glass into a vacuum, are not only inflected toward the glass; but if they fall too obliquely, they will revert back to the glass, and be totally reflected: this reflection cannot be owing to any resistance of the vacuum, but merely as the attracting power of the glass. This appears farther from hence: if you wet the posterior surface of the glass, the rays, which would otherwise have been reflected, will pass into and through that liquor: which shews that the rays are not reflected, till they come to that posterior surface of the glass, nor even till they begin to go out of it; for if at their going out they fall into any liquor, they are not reflected, but persist in their course, the attraction of the liquor counterbalancing that of the glass.

From this mutual attraction between the particles of light and other bodies, arises the reflection and refraction of light. The determination of any moving body is changed, by the interposal of another body. Thus light, meeting any solid body, is turned out of its way and reflected: but with this peculiar circumstance--it is not reflected from the body itself, but by something diffused over the surface of that body before it touches it: it is the same thing in refraction. The rays refracted come very near the refracting body, yet do not touch it. Those that actually touch solid bodies, adhere to them, and are as it were extinguished and lost.

This entirely agrees with the curious observation of an ingenious writer. "It is common to admire the lustre of the drops of rain, that lie on the leaves of coleworts and some other vegetables. Upon inspecting them narrowly I find the lustre rises from a copious reflection of the light from the flattened parts of its surface, contiguous to the plant. When the drop rolls along a part which has been wetted, it immediately loses all its lustre. The green plant being then seen clearly through it, whereas in the other case it is hardly to be discerned.

"From these two observations laid together, we may conclude, the drop, when it has the lustre, does not really touch the plant, but hangs in the air at some distance from it by the force of a repulsive power: for there could not be so copious a reflection of light from its under surface, unless there were a real interval between it and the surface of the plant.

"Now if that surface were perfectly smooth, the under surface of the drop would be so likewise, and would therefore reflect the image of the illuminating body like a piece of polished silver; but as it is rough, the under surface of the drop becomes rough likewise, and so reflecting the light copiously in different directions, assumes the colour of unpolished silver."

Again: Rays passing from a more rare into a more dense medium, are turned out of their right line, because more strongly attracted by the denser medium.

Rays of light differ in respect of refraction, reflection, and colour. Those that agree in the first of these agree in all, and may therefore be termed *homogeneal*: colours exhibited by them we may call *homogeneal colours*. This being premised, we may observe, 1. That the sun's light consists of rays variously refrangible. 2. The rays variously refrangible, when separated from each other, exhibit different colours. 3. That there are as many simple, homogeneal colours, as there are degrees of refrangibility. 4. A composition of all the simple colours is requisite to constitute whiteness. 5. The rays of light do not act upon one another in passing through the same medium. 6. Neither do they thereby suffer any refraction. 7. The sun's rays contain all homogenous colours, which may therefore be called *primitive*.

As some rays of light are less than others, so they are more refrangible: those which are most refrangible, constitute *violet* colour—that is, the smallest rays excite the most languid colour. Those which are largest, and so least refrangible, constitute *red*, the most vivid colour. The other rays excite intermediate sensations, according to their respective size and refrangibility.

Bodies reflect, instead of transmitting light, that is are opake, not transparent, not for want of pores; but either because of the unequal density of their parts or the magnitude of their pores. Either *their* pores are empty, or they are filled with matter of a different kind, whereby the rays are variously refracted and reflected till they are quite absorbed.

Hence paper and wood are opake, while glass is transparent; for in the confines of parts alike in density (such as those of glass and water) there arises no refraction or reflection, by reason of the equal attraction every way; so that the rays which enter the first surface pass strait through the body. But in the parts of wood and paper, which are unequal in density, and contain much air in their large pores, the refractions and reflections are very great, so that the rays cannot pass through them, but are bandied about till they are extinguished.

Hence opake bodies become transparent when their pores are filled with a substance of equal density, as paper dipt in water or oil: and, on the contrary, transparent bodies, by emptying their pores or separating their parts, become opake. Thus salts and wet paper become opake by drying, glass by pulverizing. Yea, water itself, if beat into froth, loses its transparency.

That light is corporeal cannot now be doubted, having been proved by a thousand experiments. By reflection and refraction it may be turned more or less out of its way, according to the different densities of the reflecting or refracting medium. Its rays in their progressive motion may be intercepted by the interposal of any opake object: and when this is removed, they proceed again in the same strait course as before. They may likewise be contracted into a less, or diffused through a larger space, while the quantity of light continues the same, neither encreased nor diminished. So in the focus of a burning glass, all the rays which would otherwise pass directly through the glass, are contracted into one bright spot, while the circumambient space for the breadth of the glass is deprived of its light and left shaded : and the action of light, thus condensed, is proportional to its quantity, and produces all the effects of the most intense fire, yea, such as no culinary fire will produce. Whence it is plain that fire and light are essentially the same, and that fire is only condensed light.

The materiality of light is farther confirmed by its motion; for vision is propagated through this medium successively, as sound is through air. This has been demonstrated from the eclipses of Jupiter's satellites; for the satellite having been hid behind the planet, it requires a certain time after it emerges before its light can reach the eye; namely, seven minutes and a half, which is a motion six hundred thousand times swifter than that of sound through the air.

The quantity of elementary light is *cæteris paribus*, every where the same at the same distance from the sun: but its action is more or less intense, as the rays are more direct or oblique. These are in a continual vibrating motion, going and returning to and from the resisting medium, in exceeding short and imperceptible intervals, which makes the element seem to be at perfect rest. All the rays are refracted and reflected alternately; so that the same incident ray, which is refracted at one interval, is reflected at the next: this is visible in transparent mediums, where the rays fall upon glass, water, and the like; but in opake bodies, though the fact is the same it is not so sensible. When the rays fall upon glass, they are reflected one moment and transmitted the next: and this vibrating motion seems to be essential to light, when its rays are put into motion.

In talking of light and sound we are apt to confound the sensation with the motion of the medium that excites it. Thus in a deep calm we say, There is no air,—because we feel none, though there is really the same quantity of air in equal space as if it blew a storm. And so in deep darkness we say, There is no light in the room, although there is supposed to be as much light there as there was at noon day: only its rays are quiescent, and make no impression upon the visive organs.

Sound is said to move about fourteen miles in a minute, which is performed thus:—the stroke given by the sounding body to the contiguous air, is communicated to the next, and so on till it reaches the ear.

The oscillations of the air are required to succeed each other with a certain velocity; and in order to render them audible, they must not be fewer than thirty in a second of time. But the more frequent these sonorous waves are in a given time, the sharper is the sound heard, and the more strongly does it affect us, till we come to the most acute of audible sounds, which have 7520 tremors in a second.

Acute sounds are, in general, yielded from bodies that are hard, brittle, and violently shook or struck; grave sounds are from the contrary. Cords or other bodies, that yield the same number of vibrations in a given time, are said to be *unison*; as those which make double the number of oscillations in that time, yield a tone that is an octave, or eight notes higher; and other proportions betwixt the number of the vibrations, have different names assigned to them in a musical scale. The shorter cords produce sharper tones, and the reverse in a proportion directly as their lengths; also those, which are more stretched afford sharper sounds.

The sound, whether acute or grave, strong or weak, is carried through the air about 1038 Paris feet in a second, and that with an uniform velocity, without abating in the larger distances. But a contrary wind, causing the vibrations to extend more slowly, retards the progression of sound about one-twelfth of its velocity. Density and dryness of the air increase the sound, as the rarefaction and moisture of the air lessen it: hence, in summer time sound moves swifter; and in Guinea, it has been observed to pass at the rate of 1398 Parisian feet in one second.

Plutarch says, Deers and horses are, of all irrational creatures, the most affected with music: Mr. Playford says the same thing, and adds, "Myself, as I travelled some years since near Royston, met about twenty stags upon the road, following a bagpipe and violin, which, when the music played, went forward, when it ceased they all stood still; and in this manner they were brought from Yorkshire to Hampton Court. Lions likewise, and elephants are susceptible of the powers of music; so are many dogs, and most, if not all, singing birds." A late author gives a stranger account still.

Monsieur de ———, captain of the regiment of Navarre, was confined in prison six months: he begged leave of the governor that he might send for his lute. After four days he was astonished to see, at the time of his playing, the mice come out of their holes and the spiders descend from their webs, which came and formed a circle round him, to hear him with attention. This at first so surprised him that he left off, on which they all retired quietly into their lodgings. It was six days before he recovered from his astonishment; he then began to play again—they came again, and in still increasing numbers, till after a time he found a hundred of them about him.

I saw a very large and fierce lion which was then kept at the infirmary at Edinburgh, quite transported with the sound of a bagpipe, and rolling upon its back with the utmost satisfaction. I saw likewise, the old lion in the Tower of London listen with the utmost attention to a German flute; mean time a young tiger leaped up and down incessantly till the music ceased. So it may be literally true,

Suetus Amphion lenire tigres.

Light is propagated about two hundred thousand miles in a second, after the very same manner as sound: The sun impresses the contigious part of its visive atmosphere: (light seems to be the atmosphere of the sun, as air is of all opake bodies). That part impress esthe next, and so on, till it reaches the eye.

All sensation is from contact of feeling; and when the object is not in immediate contact with the organ it affects, touches, or impresses, by an interposed medium. By this means the soul perceives or feels the object by the proper organ: and thus, seeing is in effect, the feeling of the eye; hearing, the feeling of the ear.

From all our experiments it appears, that the particles of light are extremely minute. Probably they are the very smallest and last divisions of matter which, being perfectly solid, cannot receive any other form: so minute are they as to pass freely even through the pores of glass, which no other fluid can penetrate.

All other bodies are immersed in this universal fluid, the common medium of all their actions on each other. But amidst all the changes of compound bodies, all the forms they successively put on, this simple element remains for ever fixed and immutable.

As to fire, or condensed light, all bodies whatever fly or recede from it, in proportion to its density: and this seems to be its first and most essential property, that no other body can exist with it, or bear its immediate action. So far as it prevails, it dissolves the closest and strongest cohesion of parts in all other bodies, and reduces them into so extremely minute particles, that they evaporate in air. And herein is an essential difference between this and all other dissolvents in nature, that the substance dissolved cannot unite with the dissolvent without destroying its action.

When salt dissolves in water, iron in aqua-fortis, or gold in aqua-regia, the substance dissolved is equally diffused through the dissolvent, so as to incorporate with it; but none of the things dissolved by fire can mix or incorporate with it: they all fly off in vapour, otherwise the fire is presently extinguished.

Elementary light then, the rays of which when condensed take the name of fire, is an element of a peculiar kind, not subject to the mechanical laws of other bodies. Now, if we suppose a material fluid, void of gravity, pressure, or any other mechanical power, all gravitating bodies will move through such a fluid, as freely as *in vacuo.*

Elementary light is a material fluid, void of gravity, pressure, or any other mechanical power. When condensed, it is pure elementary fire, which excludes all other matter out of the same space: yet it lies in the focus of a burning-glass, perfectly still and quiescent. Though it is surrounded by the air, which is a gravitating fluid, pressing equally every way, yet this immechanical element is not at all affected by it, so as to rise or fall in it, or in the least to alter its state either of rest or motion, which must necessarily happen were it endued with gravity, or the other mechanical properties found in other bodies.

And that the rays of light, in their progressive motion, do not press, resist, attract, or at all disturb each other, is evident from facts, though they come from every point of space that can be within the optic angle of the eye. Thus two men standing at a distance and looking at each other, see one another at the same instant and that by means of rays, which act in contrary directions without the least resistance. And any number of other men, standing in any position, may see the same men in the same instant, by rays which cross each other without any interruption, in all possible angles. But in sounds which move through a gravitating resisting medium, the case is quite different. For a multitude of sounds, from different sonorous bodies, cannot be distinctly heard: particularly, when they come to the ear, in many different directions. For the undulations of the resisting medium, mixing with, and disturbing each other, confuse the sensation, throwing all together, indiscriminately to the ear. Thus when a multitude of people are all talking together, the ear receives only a confused hum or murmur; whereas the eye can perceive all or any one of them distinctly and without confusion.

Indeed nothing is more sure, than that gravity, pressure, resistance, and all those affections of bodies which are termed their mechanical powers, are not intrinsic or essential to them. For since matter is purely passive, and can only act as it is acted upon, it follows, that the active force or energy, which we observe through the whole material system, must be the effect of some intrinsic, non-essential cause. And such a cause is light. But then the actions of this can never be mechanically accounted for. How this immechanical fluid acts upon other bodies, and determines their mechanical powers, we can no more explain than how the soul acts upon the body, or the mind upon matter. But we are sure this is not done by weight, pressure, resistance, or any mechanical property whatever.

" But what are the *general laws of nature?*" They are plainly the rules or principles, by which the Governor and Director of all things, has determined to act. Accordingly what we call *mechanism,* is indeed the free agency and continued energy of the author and director of nature. All the necessary motion of bodies therefore, and all the laws and forces whereby it is communicated and preserved, are the continued, regular will, choice and agency of the first cause, and incessant mover and preserver of the universe.

By the help of this admirable, this first made, because most necessary creature, light, all the animal world is enabled to go here and there, as their occasions call. We can with pleasure behold the glorious works of God: we can view the glories of the Heavens, the beauties of the flowery fields, the gay attire and exquisite garniture of many creatures. We can with admiration see the great Creator's wonderful art in the parts of animals and vegetables. In a word, we can behold the harmony of this lower world, and of the globes above, and survey his exquisite workmanship in every creature.

It is a great instance of his providence, that so necessary as light is, it is not long in passing from place to place. How inconvenient would it be, were the motion of it no swifter, than that of the swiftest bodies on earth, such as of a bullet out of a great gun, or even of sound itself? Did it move at the rate of the first, it would be above thirty-two years in coming from the sun to us, (according to the *common* computation of the sun's distance,) above seventeen years at the rate of the second motion. The inconvenience of this would be, its energy would be greatly abated; its rays would be less penetrant, and darkness would be dissipated, with greater difficulty, especially by the fainter light of our sublunary luminous bodies. But passing with that prodigious swiftness, (from the sun to us in seven or eight minutes) we receive with security and speed the kindly effects of that noble and useful creature.

Another thing worthy of consideration is, the inconceivable extension of light. It is as unlimited as the universe itself, as is manifest from our seeing some of the most distant objects, the heavenly bodies, partly with the naked eye, partly with the help of instruments. And had we instruments of power equal to the extent of light, the luminous bodies in the utmost parts of the universe, would doubtless be visible too. Hereby we have a ken of those many glorious works of the infinite Creator, which we can improve to some of the noblest sciences, and most excellent uses of our own globe.

One species of *lucid* bodies are termed *phosphori*: of which some are natural, others artificial. Natural phosphori emit light without any art or preparation. Such are glow-worms, and several sorts of shining insects. Such are rotten wood: the eyes, blood, scales, flesh, and feathers of some animals. Diamonds likewise when rubbed emit light, to one who has stayed some time in the dark. But before the diamond is brought into the dark room, it should lie eight or ten seconds in the sun-shine. It will then shine in the dark twelve or thirteen minutes: but its light gradually weakens all the time.

But it is remarkable, that some diamonds have this property of imbibing the sun's rays, and shining in the dark, and others not, though there is no other discernible difference between them. Nor is there any rule of judging, which diamonds have this property, and which have not. Their brightness, their purity, their size, their shape, contribute nothing to it.

Sulphur and sugar when pounded in the dark, will likewise emit light; as will the backs of horses or cats, when rubbed with the hand, and sea-water, yea and some mineral waters, briskly agitated. But no natural phosphorus shines always, or gives any heat.

Artificial phosphorus is made chiefly from human urine. But it may be made from blood, or hair; or indeed from any part of an animal, which yields an oily distillation. It is at first of the consistence of hard wax; but dissolves in all kinds of distilled oil. With solid phosphorus one may write on paper as with a pencil, and the letters will shine in the dark. A little piece of it rubbed between two papers, takes fire presently. It burns vehemently, and penetrates deeper into the flesh than common fire. It never spoils, if kept in a phial full of water. Liquid phosphorus does not keep long.

If the face or hands be smeared with this, they will shine in the dark, yet without any hurt to the skin.

If phosphorus be put into a long phial, of which three fourths are filled with water, it will frequently send up corruscations, which will pierce through the water, and expand themselves with great brightness in the upper part of the phial.

If we compare this with lightning, we may observe, that as in this the fire passes alternately through the water, so in that the flashes, which come at intervals, pass uninterupted through the most dense clouds and thickest rain. But this is usually in warm weather, not in winter. And it is the same with phosphorus. It very frequently flashes in warm weather, but very rarely in winter.

Again. The flame of lightning is generally inoffensive, and does not set fire to any thing. In like manner the flashes of phosphorus are harmless, and do not set fire to the most combustible matter. But when condensed phosphorus is set on fire, it burns terribly. And in the same manner lightning, when condensed, burns trees, houses, or whatever it comes near. Phosphorus while burning, acts as a corrosive, and when it goes out, forms a menstruum, which dissolves gold, iron, and other metals. Lightning melts the same substances.

Another kind of artificial phosphorus, is a preparation of the bononian stone. This stone is of no certain figure, but is sometimes round, sometimes oblong, or lenticular. They are usually as big as an orange, but very light, considering their bulk. They are of various colours, some ash-coloured, some blue, and some almost white. When this stone is prepared, it receives light, but in very different degrees, either from the sun, the moon, common day-light, or a flame. After it has been exposed a few minutes to any of these, it shines in the dark like a burning coal, with such a light as is sufficient to read by, if the letters be held near the stone. It does not retain its light long, but requires often renewing. When well prepared, it will retain this virtue for five or six years. It appears to most advantage, if brought into a dark room, after being held in the sun.

3. When the rays of light fall on opake bodies, they are variously reflected to our eyes, according as the surface of those bodies are variously disposed. And hence arises our sensation of *colours*. These, as they exist in the coloured bodies, are only the dispositions of their surface, to reflect such particular sorts of rays. White bodies reflect all rays every way, without any separation of them. On the contrary black bodies imbibe all the rays, and reflect none or very few, whereas *blue, yellow*, and *red* bodies, reflect only one particular sort of rays. The smallest sort of rays are supposed to be blue; the next yellow, the largest red.

To be a little more particnlar. There are eight true *primary* colours, which are red, yellow, green, blue, violet, purple, orange, and indigo. All the rest are compounded of these, and are termed *secondary* colours. But the more compound any colour, the less vivid it is. And by too much composition they may be diluted and weakened till they are destroyed. The most extraordinary composition of all is that of *whiteness*. For to this five at least of the primary colours are required, as also, that they be mixed in a certain degree. And hence white is the ordinary colour of light: light being an assemblage of all colours.

The transmutation of colours by mixing them together, is not real, but merely apparent. Thus mix blue and yellow powders, and they appear green. But view them with a microscope, and the blue and yellow particles are seen as distinct from each other as before.

To produce *black*, the particles must be less than those which exhibit any other colour. Where they are greater, there is too much light reflected to constitute this colour. But if there be a little less than forms the indigo, the body appears intensely black.

And hence it appears, why fire and putrefaction turn many substances black. They divide them into exceeding small particles, which then absorb, instead of reflecting the light. Hence also it appears, why glass ground very elaborately with sand on a copper-plate, makes the sand together with what is worn off from the glass and copper, become very black: likewise, why black substances exposed to the sun, are hot sooner than any other. This may partly proceed from the multitude of refractions in a little room, partly from the easy commotion of so small particles, and from their imbibing his rays. Hence also we learn, why blacks are usually inclined to a bluish colour. Black borders on indigo, and therefore reflects indigo-rays, if any.

To try if black bodies receive heat more than others, Mr. Boyle whited one half of a tile, and blacked the other, and then exposed it to the summer sun. While the white part still remained cool, the black part was grown very hot. For farther satisfaction he exposed to the sun a tile, part of which was blacked, part white, and part of its natural red: and after a while found the black part hot, the red warm, and the white cool.

"I laid on the snow, (says Dr. Franklin,) little pieces of broad cloath, of divers colours, black, deep blue, light blue, green, purple, red, yellow, white, in a bright sunshiny morning. In a few hours the black (being warmed most) was sunk lowest, the dark blue almost as low, the light blue not quite so much, the other colours less as they were lighter, and the white not at all. This was an easy and certain way of shewing which was heated most."

All the *secondary* colours of natural bodies proceed from their reflecting two or more sorts of rays together, and absorbing the rest.

Glass, crystal, diamond, and other transparent bodies, lose their transparency, and are white, when reduced to powder: the change of texture causing them to reflect the rays which before they transmit.

White loaf-sugar, melted over the fire, without water, first turns brown, afterwards black. And a single grain of this tinges a quart of fair water with a beautiful yellow. Violets, roses, carnations, and most flowers lose their colour, by being long in the open air. And by the same means blue essential oil of chamomile-flowers changes to a dirty green.

Many colours may be produced, destroyed, and regenerated, upon simple mixture. Let dried rose-leaves stay awhile in spirits of wine, and they lose their colour without tinging the liquor. But add a little oil of vitriol, and it turns red: put in a little urinous spirit, and the red changes to green, which by adding a little more oil of vitriol, turns to a red again.

Make a slight infusion of bruised galls in water, so as not to discolour it. Make also a weak infusion of green vitriol in water, which will be still transparent. Yet mix them together, and an inky blackness will immediately arise. But add a little oil of vitriol, the blackness will vanish, and the liquor be transparent again. Yet the blackness may be recalled by adding a little salt of tartar.

If a little bruised camphire which is very white, be put into transparent oil of vitriol, the camphire will dissolve, and tinge the liquor first brown, and at length a fine black. But upon the addition of fair water, the blackness entirely vanishes, and the camphire regains its native whiteness.

A transparent infusion of sugar of lead in water being wrote with, when dried becomes invisible. But the bare fumes of another transparent liquor, namely, infusion of quick lime and orpiment in water, will quickly make the invisible writing black and visible.

And not only secondary, but primary colours are producible by simple mixture. If the sun's rays pass through two pieces of differently coloured glass, suppose a blue and a yellow piece laid on each other, and these rays are received upon white paper, they produce a beautiful green. A mixture of seven, or even five, original colours, will make a pure white. If different coloured flames be brought to mix, the experiment is made to perfection.

Flames from different bodies are of different colours.

The flame of camphire is white; of sulphur, blue; of white-wax, inclining to yellow. For making experiments, oil may be impregnated with different metals, so as to exhibit their particular flames.

4. Air is the ordinary vehicle of sound, which is the fainter, the more remote the sounding body is. It is also lessened, and sometimes quite interrupted either by contrary winds or thick vapours floating in the air. It is supposed, that the sounding body, excites a kind of undulation or tremulous motion in the air, raising as it were waves of air, one of which impels the other till they reach the ear.

Sound moves but little quicker by having the wind with it, as it moves at least thirty three times faster than the most violent wind we know. But it is heard much farther thereby.

That air is the *grand vehicle* of sound, appears from various experiments. A bell in an unexhausted receiver, may be heard at some distance; but scarce at the smallest, when it is exhausted. But it is not the only one, water too will convey sound. If you strike a bell under water, the sound is heard plain, only not so loud, and also a fourth deeper. And a sound made in air, is heard under water, with just the same difference.

Sounds commonly move a mile in about nine seconds and a quarter. If a gun be discharged with its mouth to us or from us, the report comes to us in the very same time. It always moves the nearest way, and equally swift from the beginning to the end of its motion.

If the undulating air strikes against hard concave bodies, it rebounds, and occasions what we call an *echo*. As often as sound strikes perpendicularly on a wall, behind which is any vault or arch, or even a parallel wall, so often it will be reverbrated in nearly the same line. For a multiplied echo, there must be a number of walls and cavities, either behind, or fronting each other.

The echo in Woodstock-park returns very distinctly, in the day seventeen, in the night, twenty syllables. There is an echo on the bank of the river Nassa, between Bingen and Collentz in Germany, which repeats what is said seventeen times. And what is still more peculiar, the person who speaks is scarce heard at all, but the repetition clearly, and with surprising variety: the echo seeming sometimes to approach nearer, and sometimes to be farther off. One person hears only one voice, another several: one hears it on the right, another on the left.

Two miles from Milan there is a still more surprising echo. It returns the sound of a pistol fifty-six times. The first repetitions follow one another very quick; but they are more distinct in proportion as they decay. There are two parallel walls, which beat the sound back upon each other.

5. The fine *effluvia* from odorous bodies, when they reach our nostrils, excite the sensation of *smelling*. Some bodies emit these most when they are moist: some only when they are warmed or heated. From all such bodies, innumerable particles flow, which according to their various size, figure, and motion, variously affect the olfactory-nerve. But what particular motion, size, or figure, is required in order to any particular smell, who is able to explain?

These effluvia indeed are inconceivably small: so that amber and divers other odorous bodies, emit them for many years, without any discernable loss, either as to bulk or weight.

Mr. Boyle shews, 1. That the number of particles thus emitted, is exceeding great. 2. That they are of a very penetrating nature. 3. That they move with vast swiftness and in all directions. 4. That there is often a wonderful congruity between the bulk and shape of these effluvia and the pores of the bodies they penetrate, and lastly, that they may excite great motions, and thereby make great changes in organized bodies.

That effluvia are emitted to a very great distance we learn from hence, that wines grow turbid in the hogshead, precisely at the time that the grapes are ripe in the country whence they were imported. That they are very penetrating even without losing their virtue we have a proof from the loadstone, whose effluvia pass through the most solid bodies without any change of their force. That they occasion great changes in organized bodies we have a remarkable proof in a case lately published by Dr. Heister: "Making an afternoon's visit to the Rev. Mr. Sentag, he received me in an apartment where there were three or four flower-pots with white lillies. I asked him if he did not find his head affected when he continued long in the room where they were, and told him physicians thought them dangerous, and I myself could not bear them. I therefore begged the window might be opened that the effluvia might be dispersed.

"He ordered the window to be opened, and replied, he found no inconvenience from them, being a tall, strong, healthy man. But the smell being still too powerful for me, I was obliged to take my leave of him sooner than I intended.

"The night following he was seized with an apoplexy: Dr. Bayer and myself were sent for; we found him with his eyes wide open, but without speech, sense, or motion. I told Dr. Bayer what had passed the day before: we ordered bleeding, blisters, and strong friction of the soles of the feet, head, and hands, with the other remedies usual in those cases, but without success; for the next morning he began to rattle in the throat, and soon after died."

This may admonish those to whom these odours are not sensibly prejudicial not to stay long within the sphere of their activity.

In some places effluvia from the earth produce many effects on the surface of it. The bubbling and boiling fountains in England and other countries are chiefly occasioned by the bursting up of their effluvia. Our burning well in Lancashire has no peculiar property in its water; but an inflammable vapour rising through it makes it boil and bubble on the surface. And this vapour, as soon as set at liberty from the water, will take flame at a lighted candle.

The famous boiling spring near Montpelier is likewise no other than common water, through which a vapour of the same kind makes its way; indeed, all the springs thereabouts bubble more or less, the vapour making its way through the whole surface of the earth. Water taken out of that spring has no such property nor any peculiar taste or virtue. What is a farther proof is, the cracks of the earth thereabouts all perspire strongly a vapour of this kind; so that if straws be laid on the surface they will be blown up; and if a hole be any where dug in the ground, and water poured into it, it will boil up in the same manner as the spring.

The like sort of springs are common in Switzerland, and some other places: these are known to be owing to effluvia from beneath, by the water of them being cold. But there are others which actually boil, and are hot enough to boil an egg: such are the famous boiling fountains of Solfatara, near Naples.

From these various springs we find that there is much variety of this kind of exhalations: some being cold and dry, some of a bituminous nature, and not actually cold, as our's in Lancashire; some hot, as those in the sweating vaults and caverns, and in the mountains of Italy. Others are of a poisonous nature, containing particles of arsenic, or other poisonous minerals.

6. Many bodies are tasteless; but some even of these may contract a very strong *taste* (as do several metals) when they are resolved into a fine powder. Some bodies by several other changes, acquire tastes, which they had not before, or variously increase, lessen or alter their taste. Hence it has been supposed that all tastes proceed from salts, which are often so enveloped, that they cannot exert their power. But if the containing bodies are dissolved by fire or liquors, then they variously affect the nerves in the tongue and palate: and hence arise all the various sensations of taste. But what particular size, shape, or motion of the particles is required to produce any particular taste, all our skill cannot determine.

7. Of the properties which we perceive by *feeling*, the chief are *moistness, dryness, heat,* and *cold*. There is no heat without fire, or at least some disposition of the heated body to take fire. If the particles of it, rapidly agitated, strike against another body, tear and dissolve it; if against the body of a man, the sensation of heat arises in the mind. Some suppose *cold* consists in the rest of those particles which were so agitated before. Others think this would not suffice to pruduce that accute pain which we sometimes feel from cold; and therefore suppose there are positive frigorific particles, which move on in strait lines, and so not only destroy the circular motion which is required for heat, but likewise penetrate the body, and sharply affect the extremities of the nerves.

8. *Gravity* and *levity* have likewise been reckoned among sensible qualities; but properly, there is no such a thing as levity, for all bodies tend to the centre of the earth, though some are light in comparison of others. The laws of gravity are, 1. All bodies on the earth tend to a point which is (nearly at least) the centre of the globe. 2. In all places equidistant from the centre, the force of gravity is nearly equal. 3. Gravity equally affects all bodies, without regard either to their bulk or figure: so that were it not for the resistance of the medium, the greatest and smallest bodies, the most dense and the most rare, would descend equal spaces in equal times. Thus gold and feathers descend alike in an exhausted receiver. 4. This power increases as we descend to the centre, and decreases as we ascend from it, and that as the squares of the distances. Thus, at a double distance, things have but a quarter of the force. 5. Those things swim in fluids which are specifically (that is bulk for bulk) lighter than those fluids.

This gravitating power seems to be congenial to matter: it penetrates even to the centre of the sun and other heavenly bodies, without any diminution of its virtue; and it acts not according to the surface of bodies, as mechanical causes do, but according to the quantity of matter they contain. That it is an original law of nature immediately impressed by the Creator, without dependance on any second cause at all, may appear from the following considerations: 1. Gravity does not require the presence of the gravitating or attracting body. 2. The distance being the same, the velocity wherewith gravitating bodies move, depends on the quantities of matter in the attracting body; and the velocity is not changed, let the mass of the gravitating body be what it will. 3. If gravity depends on any known law of motion, it must be some impulse from an extraneous body: whence, as gravity is continual, a continual stroke must also be required. Now, if there be any such matter continually striking on bodies, it must be subtle enough to penetrate all bodies. But how should matter, subtle enough to penetrate the hardest bodies, and so rare as not sensibly to hinder the motion of any, be able to impel such vast bodies toward each other with such force? How does this force increase according as the mass of that body, toward which any body moves increases? Whence is it that all bodies at the same distance from the body gravitated to, move with the same velocity? And how can matter, which only acts on the surface of the bodies themselves, or of their internal particles, communicate such motion as in all bodies shall exactly follow the proportion of the quantity of matter in them?

But after all comes Mr. Hutchinson, calls Sir Isaac and all his followers senseless, unphilosophical blockheads, and to solve all the difficulty in a moment, supposes the sun to be the centre of the whole universe, and to project light every way through every point of space, to the utmost circumference of it. When this light arrives at the circumference, it is condensed into larger masses and returns in the form of spirit or air, through every point of space to the sun. There it is again comminuted into light by the immense fire, and so issues out again to the circumference. And this double impulse of light moving outward, and spirit moving inward, causes the motion of all the heavenly bodies, both round their own axis and round the sun. But to wave that gross absurdity of supposing every point of space to be continually filled with light, and every point of it to be filled with spirit at one and the same time, (which is flatly impossible, since both are material, and two particles of matter cannot co-exist in the same space:); how does this remove the difficulty at all? How does it help us forward a hair's breadth? For what impels light outward, or spirit inward? It can be no mechanical power: it must then be the finger of God; and if so, what have we gained? May we not as well say at once (as go thus round about); "Gravitation can be no otherwise accounted for than by allowing the direct, immediate power of God, operating through the whole universe?"

But beside the attraction of gravity there is another species of attraction, between the minute particles whereof bodies are composed. These attract each other at or near the point of contact, with a force much superior to that of gravity. It is by this attraction of cohesion that the atoms, or insensible particles of bodies are united into sensible masses. Hereby numberless phenomena may be accounted for, which are otherwise inexplicable: such as coagulation, crystallization, and and the ascent of fluids in capillary tubes. Such likewise are fermentation, animal secretion, and many others. Thus nature will be found very simple and conformable to herself, performing all the great motions of the heavenly bodies, by the attraction of gravity between those bodies, and almost all the motions of their several parts, by this attraction diffused through every particle. Sir Isaac thinks, that without these two principles there would be no motion in the world: and without the continual operation of them it could not long continue, considering the vast and constant diminution of motion by various other causes.

Mr. Hervey's observations on this head are strong and beautiful.

"The fundamental laws of our modern astronomy are *projection* and *attraction*: one the all-combining cement, the other the ever-operative spring of the mighty frame. In the beginning God impressed a proper degree of motion on each of the whirling orbs. This, if not controlled, would have carried them on in strait lines, till they were lost in the abyss of space; but the principle of *gravitation* being added thereto, determined their course to a circular form. And how necessary for the conservation of the universe, is both the one and the other? Were the projectile power to cease, all the harmoniously-moving spheres would fall into the central fire. Were they gravitating, they would exorbitate into wild confusion, or by their rapid whirl be dissipated into atoms. But the impulsive and attractive energy, being nicely attempered to each other, the various globes persevere in their radient course, without any interruption or diminition.*

"How extensive, and how diversified is the force of this single principle of *attraction?* (Understanding by the word, that of cohesion, as well as of gravitation!) It penetrates the very essence of all bodies, and diffuses itself to the utmost limits of the mundane system. By this all those vast worlds of matter hang self-balanced on their centres. And to this is owing an effect of a very different nature, the *pressure* of the atmosphere, which, though a yielding and expansive fluid, yet by virtue of an attracting energy surrounds the whole globe of earth, and encloses every creature thereon, as it were with a tight bandage: an expedient absolutely necessary to preserve the texture of our bodies, and indeed of every animal. Urged by this, the *rivers* circulate with a never-failing current, along the veins of the earth. Impelled by the same mysterious force, the *nutricious juices* are detached from the soil, and, ascending the trunks of trees, find their way through millions of the finest meanders, in order to convey vegetative life into the smallest branches. This confines

* All this is spoken on the Newtonian Hypothesis.

the *ocean* within its bounds. Though the waves thereof roar and swell, yet, checked by this curb, they are unable to pass even the slightest barrier of sand. To this the *mountains* owe that unshaken firmness which laughs at the shock of careering winds. By virtue of this invisible mechanism, without any instrument of human device, thousands of tons of *water* are raised every moment into the regions of the firmament. By this they continue suspended in the air without any cistern to contain them. By the same variously-acting power they in due time drop down again in gentle falls of *dew*, or are precipitated in copious showers of *rain*: they slide down in fleecy flights of *snow*, or dart in clattering showers of *hail*: this occasions the strong *cohesion* of *solid bodies*, without which our large machines would be utterly useless, and the nicer utensils of life elude our expectations of service. In short, this is the *ballast* which composes the equilibrium, and constitutes the stability of things: this the great *chain* which forms the connexion of universal nature, and the mighty *engine*, which in good measure accomplishes almost all her operations. What complicated effects from a single cause! What profusion amidst frugality!"

How extremely plausible is all this! And what pity that it is only *plausible!* but it is really no more: it is not capable of any substantial proof; I mean, with regard to the motion of the heavenly bodies, and the causes of that motion.

I do not know that any one has yet given a rational answer to Dr. Rogers' observations on that head. "The action of these two powers (*gravitation* and *projection*) is inadequate to such a motion; because, in order to produce it, the gravitating force must exactly balance the projectile: but where this done, one would destroy the other: this will appear plain if we consider the nature of these two forces. Gravitation, by which the earth attracts all bodies, is at all times uniformly exerted in right lines, from the earth to the body attracted, and acts equally on all bodies according to their densities: it is perpetual, subject to no decay, needing no reparation. But projection is a motion given to the body contrary to its nature: when given it would always continue in a strait line, if nothing hindered it, but cannot remove any obstruction without losing part of its own force. Now the obstruction given by attraction must have the same effect as obstruction given by air or ether: it must continually lessen any projectile force till that force is totally destroyed.

"A mortar elevated forty-five degrees, ejects a bomb at first in or near a right line, while the projectile force is vastly superior to the attractive, afterwards in a curve: for the moment the two forces are in equilibrio, in a segment of a circle: then in a curve less and less bent, till it falls in a right line to the centre of gravitation.

"This is the nature of all projectiles; nor can any projectile, thrown in any direction by any force of attraction, produce a circular motion: much less an elliptical one, such as that of the earth. Besides, what physical reason can be assigned why the earth, being nearer the sun in winter, the gravitating force does not increase; and why the projectile does not increase in summer, when it is farther from the sun, to the entire destruction of one or the other?

"A third motion also is supposed to be primarily impressed on the earth, namely round its own axis. But nothing can be more plain than that a body so strongly attracted by the sun as to keep it from flying off in a tangent, must have its circular motion presently stopt; as the side next the sun must be attracted most, the attraction of all the planets co-operating thereto.

"To make this plain, I hung a loadstone to a small string, and gave it as many turns as would continue its revolving motion ten minutes and a half, when no iron was near; but on bringing a piece of iron near, it stopped. The iron being removed, it recommenced its circular motion, which lasted for a minute more. Hence it is evident, that did not some force continually act upon the earth to keep up its motions, the attractive power of the sun would soon stop, at least the diurnal one.

"The friction likewise of the ether must be considerable. Else why might not the earth revolve in twenty-four minutes as well as twenty-four hours? Indeed, this seems to be one great use of the ether, to prevent the too rapid motions of the planets. And as the earth floats in the air, so does the sun in the ether, his proper atmosphere, which extends to the utmost limits of his system, and is the medium funiculi or hami, by which he attracts all the planets and comets, and prevents their flying out of the system.

"Neither will gravitation at all account for the motion of comets. That in 1680 descending from an immense height perpendicularly toward the sun, rose from him again with equal velocity. Now as its access to, and recess from the sun, were made in strait lines, while they were making, the projectile force must cease. But to stop any projectile, is to destroy its motion. How came it then to be so strongly exerted in the Perihelion? Was there a continued miracle, a fresh projection given? Or did it rebound? What, from the yielding ether!

"Again. This comet, during half its circuit round the sun, was distant from it but one third of the moon's distance from the earth. The attractive force therefore was then vastly increased; and the projectile being destroyed, it must have impinged on the sun long ago, had there been no other force to prevent it. It is clear then upon the whole, that the motions of the heavenly bodies, cannot be accounted for, by attraction and projection.

"How then can they be accounted for? Possibly thus. The earth being an oblate spheroid, objected to the sun in an obliquity of 66 degrees 30 minutes, (the same which given to the sails of a windmill, occasions its most forcible conversion) the sun's rays striking against the oblique hemisphere, as the wind against the sails of a windmill, keep it off, and at the same time make it turn on its own axis. The ether being a resisting medium, and the atmosphere (like the oars of a boat) striking therein, urges it into a progressive motion. Meantime its own gravity inclines it to the sun's centre, and of course keeps it in equilibrio, with the repelling rays.

"It is supposed likewise, that the plane of the earth's orbit, is in winter in or near the sun's axis, whence the rays are not so forcibly emitted; for which cause the earth must then come nearer, the repelling force being weaker. But in summer, being objected to the more forcibly repelling rays, it must be driven to a farther distance; whence its annual orbit must become elliptical.

"The earth's diameter being known, determines its distance from the sun. For as the diameter is 7967, the periphery 25031, which multiplied by the number of its revolutions 36,525, gives for its orbit 9,142,572: and as it moves through this orbit merely by the impulse of the solar rays, and as the gravitating force must necessarily be equal to that impelling force; so while it rolls onward one mile, it is attracted another. Consequently the preceding orbit being doubled, by the gravitating force, make in all 18,285,144. The semi-diameter of this is the distance of the earth from the sun: which therefore is neither more nor less than 2,910,364 miles.

"In the same manner we find the distance of Venus from the sun, to be 1,790,684 miles: that of Mars, 5,473,690; that of Jupiter, 34,520,432: that of Saturn, 85,727,320: and that of Mercury, 700,758.

"And as these distances are far less than those assigned by the modern astronomers; so is the magnitude of the heavenly bodies proportionably less than they suppose. For instance; the diameter of the sun, commonly supposed to be 822,148 miles, is according to this manner of calculating, 23,373 and no more. And that this is nearly the true diameter, and these the true distances appears from experiments on the transits of the planets over the sun."

The comets, Dr. Rogers thinks, are chiefly designed to repair the quantities of light continually emitted by the sun, and which are scattered and dispersed over the whole system. Their sweeping tails, which extend so many thousand miles, seem adapted to such a purpose. And as many of those particles of light, are driven to a vast distance, it is necessary they should go to the utmost limits of the system, to make such a collection.

Suppose a body fit for this, detached from the neighbourhood of the sun, it should be light, porous and spongy. And such a body would be propelled by the violence of the rays, with great velocity to a great distance. The farther it goes, the fewer rays strike upon it, and their force likewise is diminished. The comet then slowly sweeps his tail over the wide expanse, beyond the orbit of Saturn. There its cells are filled with the matter it was sent to collect; but becoming heavier, the other scale begins to preponderate, and he slowly returns toward his centre. His collection increases as he descends, which adds to his weight and swiftness, and he comes down, if very heavy, almost in a strait line; if less so, in a larger curve, till he is near the sun, where having emptied himself, and being evenly balanced with the repelling rays, he moves round in the segment of a circle, till being continually lighter, he is no longer a balance for the repelling rays, and so is driven forward thereby, and runs the same circle as before.

What a violent blow is here given to the whole fabric of modern astronomy! And how can any reasonable man subscribe thereto, till this difficulty is removed?

9. There is no need to speak particularly of those other qualities, *hardness, softness*; *firmness, fluidity*; *brittleness, toughness*; *roughness, smoothness, density, rarity*; *regidity, flexibility*; *compressibility, elasticity*. What each of these is, we know well, without any elaborate definition; and in general we know, that they all arise from the various figure, situation and texture of the particles whereof bodies consist. But farther than this we know not. What particular shape, texture, or situation, is requisite in each case, is a matter of mere conjecture.

10. Those of which we are not able to give any rational account, have often been termed *occult qualities*. Among these is usually ranked that *smypathy*, which is observed in things distant from each other. So onions in the granary sprout, while others sprout in the garden. So nothing is more common, than that if you throw a mulberry or strawberry at a woman with child, the child has the mark of one or the other, on the same part which was struck with it. And these marks grow green, yellow and red every year, just as those fruits do in the garden; and when the season of them is past, these subside, and vanish away. So women startled by a sudden sight of the moon, have stamped the figure of the moon on their children; and this figure increased or decreased just as the moon did. Opposite to this, is that amazing *antipathy*, which some things appear to have naturally for each other. Instances of which are found, not only in men, but in animals, if not in plants also.

Before we attempt to account for any of these things, we should take care to be well assured of the fact. For many of them are generally believed and vehemently asserted, which yet never had any being. Hence others run into the opposite extreme, roundly denying whatever they cannot account for. The middle way is best. First, be sure of the fact. Then, try if it can be accounted for on allowed principles. And if it can, the qualities in question are to be termed *occult* no longer. But there will still remain many secrets in nature, which we are in nowise able to account for. Indeed to penetrate the inmost recesses of nature, is above the condition of humanity. We must therefore necessarily allow, that there are in this sense many occult qualities: nay, we are surrounded with them on every side: insomuch that there is scarce any thing in the universe, that has not some qualities, which the wisest man on earth is not able to account for.

11. I have now finished what I proposed. I have given as short and plain an account as I could, of all that is certain in Natural Philosophy: in order to direct the whole to its proper end, I have now only to add a few reflections.

If we cast our eyes up to the firmament, let us seriously ask ourselves, what power built over our heads that vast and magnificent arch, and *spread out the Heaven's like a curtain?* Who garnished these heavens with such a variety of resplendent objects, all floating in the liquid ether, and regular in their motions? Who painted the clouds with such variety of colours, and in such diversity of shades and figures, as it is not in the power of the finest pencil on earth to emulate? Who formed the sun of such a determinate size, and placed it at such a convenient distance, as not to scorch or annoy, but to cherish all things with his genial heat? For a succession of ages he never failed to rise at his appointed time, or to send out the dawn as his forerunner, to proclaim his approach. By whose skilful hand is it directed, in its diurnal and annual course, to give us the grateful vicissitude of night and day, and the regular succession of the seasons? That it should always proceed in the same path, and never once step aside: that it should go on, in a space where there is nothing to obstruct, but turn at a determinate point: that the moon should supply the absence of the sun, and remove the horror of the night; that it should regulate the flux and reflux of the sea, thereby preserving the waters from putrefaction, and at the same time accommodating mankind with so manifold conveniences: that all the innumerable hosts of heaven, should perform their revolutions with such exactness, as never once to fail, in a course of six thousand years, but constantly to come about in the same round to the hundredth part of a minute: this is such an incontestable proof of a divine architect, and of the care and wisdom wherewith he governs the universe, as made the Roman philosopher conclude, "whoever imagines, that the wonderful order and incredible constancy of the heavenly bodies and their motions, whereon the welfare and preservation of things depend, are not governed by an intelligent being, is himself destitute of understanding. For shall we, when we see an artfully contrived engine, suppose a dial or sphere, immediately acknowledge that it is the result of reason and understanding: and yet, when we behold the heavens, so admirably contrived, moved with such incredible velocity, and finishing their anniversary revolutions, with such unerring constancy, make any doubt of their being the work, not only of reason, but of an excellent, a divine reason?"

But if from that very imperfect knowledge of astronomy which his time afforded, even the heathen could be so confident, that the heavenly bodies were framed and moved by a wise and understanding mind: what would he have said, had he been acquainted with our modern discoveries? Had he known the immense greatness of that part of the world, which falls under our observation? The exquisite regulation of the motions of the planets, without any deviation or confusion: the inexpressible nicety of adjustment, in the velocity of the earth's annual motion; the wonderful proportion of its diurnal motion about its own axis; the densities of the planets, exactly proportioned to their distances from the sun: the admirable order of the several satellites, which move round their respective planets; the motion of the comets equally regular and periodical, with that of the other planetary bodies; and lastly, the preservation of the several planets and comets, from falling upon, or interfering with each other? Certainly could argument avail, Atheism would now be utterly ashamed to shew its head, and forced to acknowledge, that it was an eternal and almighty Being, it was God alone, who gave to each of the celestial bodies, its proper magnitude and measure of heat, its dueness of distance, and regularity of motion: or in the language of the prophet, who *established the world by his wisdom, and stretched out the Heavens by his understanding.*

If from the firmament we descend to the orb on which we dwell, what a glorious proof have we of the divine wisdom, in this intermediate expansion of the air, which is so wonderfully contrived, to answer so many important ends at once! It receives and supports clouds, to water the earth. It affords us winds, for health, for pleasure, for a thousand conveniences: by its spring, it ministers to the respiration of animals; by its motion to the conveyance of sounds; and by its transparency, to the transmission of light, from one end of Heaven to the other. Whose power made so thin and fluid an element, a safe repository for thunder and lightning? By whose command, and out of whose treasuries, are these dreadful, yet useful meteors sent forth, to purify the air, which would otherwise stagnate, and consume the vapours that would otherwise breed various diseases? By what skilful hand are those immense quantities of water, which are continually drawn from the sea, by a natural distillation made fresh, sent forth upon the wings of the wind, into the most distant countries, and distributed in showers over the face of the earth?

Whose power and wisdom was it that hanged the earth upon nothing, and gave it a spherical figure, the most commodious which could be devised, both for the consistency of it parts, and the velocity of its motion? Who was it that *weighed the mountains in scales, and the hills in a balance*, and disposed them in their most proper places, both for fruitfulness and health? Who diversified the climates of the earth into such an agreeable variety, that, remote as they are from each other, each has its proper seasons, day and night, winter and summer? Who was it that clothed the face of it with plants and flowers so exquisitely adorned with various and inimitable beauties? That placed the plant in the seed, in such elegant complications, as afford at once both a pleasing and an astonishing spectacle? That painted and perfumed the flowers, that gave them the sweet odours which they diffuse through the air for our delight, and with one and the same water dyed them into different colours, surpassing the imitation, nay, and the comprehension of mankind? For can the wisest of men tell,

"Why does one climate and one soil endue
The blushing poppy with a crimson hue,
Yet leave the lilly pale, and tinge the violet blue?"

Who replenished the earth, the water, the air, with such an infinite variety of living creatures, and so formed, that of the innumerable particulars wherein each creature differs from all others, every one is found upon examination to have its singular beauty and peculiar use. Some walk, some creep, some fly, some swim. But every one has all its members and its various organs accurately fitted for its peculiar motions. In short, the stateliness of the horse and the feathers of the swan, the largeness of the elephant and the smallness of the mite, are to a considerate mind equal demonstration of an infinite wisdom and power. Nay, rather the smaller the creature is, the more amazing is the workmanship. When in the mite, for instance, we see a head, a body, legs and feet, all as well proportioned as those of an elephant, and consider withal that in every part of this living atom there are muscles, nerves, veins, arteries, and blood; every particle of which blood is composed of various other particles: when we consider all this, can we help being lost in wonder and astonishment? Can we refrain from crying out, on this account also, *O the depth of the riches both of the wisdom and knowledge of God! How unsearchable are his works and his ways* of creation and providence *past finding out!*

Natural instinct is another thing in animals no less wonderful than their frame; and is indeed nothing else than the direction of an all-wise and all-powerful mind. What else teaches birds to build their nests, hard or soft, according to the constitution of their young? What else makes them keep so constantly in their nest during the time of incubation, as if they knew the efficacy of their own warmth, and its aptness for animation? What else causes the salmon every year to come up a river, perhaps hundreds of miles, to cast its spawn, and secure it in banks of sand till the young ones are excluded? To go no farther, can we behold the spider's net, the silk-worm's web, the bee's cells, or the ant's granaries, without being forced to acknowledge the infinite wisdom which directs their unerring steps, and has made them fit to be an emblem of art, industry, and frugality, to mankind?

If, from the earth, and the creatures that live upon it, we cast our eyes upon the water, we soon perceive that had it been more or less rarefied, it had not been so proper for the use of man. And who gave it that just configuration of parts and exact degree of motion, which makes it so fluent, and yet so strong as to carry and waft away the most enormous burdens? Who has instructed the rivers to run in so many winding streams through vast tracts of land, in order to water them the more plentifully? Then to disembogue themselves into the ocean, so making it the common centre of commerce: and thence to return through the earth and air, to their fountain heads, in one perpetual circulation? Who replenished these rivers with fish of all kinds, which glide through the limpid streams, and run heedlessly into the fisher's net, for the entertainment of men? The great and wide sea is a very awful and stupendous work of God. Whose hand makes it ebb and flow with such exactness? A little more or less motion in the fluid mass would disorder all nature, and a small increase of a tide, might ruin whole kingdoms. Who then was so wise as to take exact measures of those immense bodies, and who so strong as to rule at pleasure the rage of that furious element? He *who hath placed the sand for the bound of these, by a perpetual decree that it cannot pass.* So that *though the waves thereof toss themselves, they cannot prevail, though they roar they cannot pass over it.*

If, from the world itself, we turn our eyes more particularly on man, whom it hath pleased the Lord of all to appoint for its principal inhabitant, no understanding surely can be so low, no heart so stupid and insensible, as not plainly to see that nothing but infinite wisdom could in so wonderful a manner have fashioned his body, and breathed into it a reasonable soul, whereby he *teacheth us more than the beasts of the field, and maketh us wiser than the fowls of heaven.*

Should any of us see a lump of clay rise immediately from the ground into the complete figure of a man, full of beauty and symmetry, and endowed with all the powers and faculties which we perceive in ourselves, yea, and that in a more eminent degree of perfection than any of the present children of men; should we presently after observe him perform all the offices of life, sense and reason; move as gracefully, talk as eloquently, reason as justly, and discharge every branch of duty with as as much accuracy as the most accomplished man breathing, how great must be our astonishment! Now this was the very case in that moment when God created man upon the earth.

But to impress this in a more lively manner upon the mind, let us suppose the figure above mentioned rises by degrees, and is finished part by part in some succession of time. When the whole is completed, the veins and arteries bored, the sinews and tendons laid, the joints fitted, the blood and juices lodged in the vessels prepared for them, God infuses into it a vital principle. The image moves, it walks, it speaks. Were we to see all this transacted before our eyes, we could not but be astonished; A consideration of this made David break out into that rapturous acknowledgment. *I will give thee thanks, for I am fearfully and wonderfully made! Marvellous are thy works, and that my soul knoweth right well. Thine eyes did see my substance yet being imperfect, and in thy book were all my members written.*

Thus, which way soever we turn our eyes, whether we look upward or downward, without us or within us, upon the animate or inanimate parts of the creation, we find abundant reason to say, *O Lord, how manifold are thy works! In wisdom hast thou made them all.*

Let us observe a little farther the terraqueous globe: how admirably are all things thereon chained together, that they may all aim at the ultimate end which God proposed in all his works! And how vast a number of intermediate ends are subservient to this! To perpetuate the established course of nature in a continued series, the Divine Wisdom has thought fit that all living creatures should constantly be employed in producing individuals, that all natural things should lend a helping hand toward preserving every species, and lastly, that the destruction of one thing should always conduce to the production of another.

This globe contains what are called the three kingdoms of nature, the *fossile*, *vegetable*, and *animal*. The fossile constitutes the crust of the earth, lying beneath the visible surface; the vegetable adorns the face of the globe, and draws much of its nourishment from the fossile kingdom. The animal is almost wholly sustained by the vegetable kingdom. If we go deeper into the earth, the rule which generally obtains with regard to the strata thereof is this: The upper parts consist of rag-stone, the next of slate, the third of marble filled with petrefactions, the fourth of slate again, and lastly, the lowest which we are able to discover, of free stone.

That the sea once overspread a far greater part of the earth than it does at present we learn not only from geographers, but from its yearly decrease, observable in many places; partly occasioned by the vast quantities of shells, and all kinds of rubbish which the tides continually leave on the shores. Hence most shores are usually full of wreck, of dead, testaceous animals, of stones, dirt, or sand of various kinds, and heaps of other things. Rivers likewise, especially those which have a rapid stream, wear away whatever they touch, particularly soft and friable earth, which they carry and deposit on distant winding shores: whence it is certain the sea continually subsides, and the land gains no small increase.

Water retained in low grounds occasions marshes. But what a wonderful provision has nature made, that many of these, even without the help of man, shall again become firm ground! More and more mossy tumps are seen therein: some of these are brought down by the water, from the higher grounds adjoining, and others are produced by putrifying plants: thus the marsh is dried up and new meadows arise; and this is done in a shorter time whenever the *sphaguum*, a kind of moss, has laid the foundation: for this, in process of time, changes into a porous kind of mold, till almost all the marsh is filled with it. After this the rush begins to strike root, and, together with the cotton-grass, constitutes a turf, wherein the roots get continually higher, and thus lay a firm foundation for other plants, till the whole marsh is covered with herbs and grass, and becomes a pleasant and fruitful meadow.

I shall add only one reflection more, with regard to the *scale of beings*. As the microscope discovers almost every drop of water, every blade of grass, every leaf, flower, and grain of earth, to be swarming with inhabitants: a thinking mind is naturally led to consider that part of the scale of beings, which descends lower and lower, from himself, to the lowest of all sensitive creatures. Among these some are so little above dead matter, that it is hard to determine whether they live or no. Others that are lifted one step higher, have no sense beside feeling and taste. Some again have the additional one of hearing: others of smell, and others of sight.

It is wonderful to observe, by what a gradual progression the world of life advances, through an immense variety of species, before a creature is found, that is complete in all its senses. And among these there are so many different degrees of perfection in the senses which one animal enjoys above another, that though each sense in different animals, comes under the same common denomination, yet it seems almost of a different nature. If after this, we attentively consider the inward endowments of animals, their cunning and sagacity, and what we usually comprehend under the general name of *instinct*, we find them rising one above another, in the same imperceptible manner, and receiving higher and higher improvements, according to the species in which they are implanted.

The whole progress of nature is so gradual, that the entire chasm from a plant to man, is filled up with divers kinds of creatures, rising one above another, by so gentle an ascent, that the transitions from one species to another, are almost insensible. And the intermediate space is so well husbanded, that there is scarce a degree of perfection which does not appear in some. Now since the scale of being advances by such regular steps as high as man, is it not probable, that it still proceeds gradually upwards, through beings of a superior nature? As there is an infinitely greater space between the Supreme Being and man, than between man and the lowest insect.

This thought is thus enlarged upon by Mr. Lock: "That there should be more species of intelligent creatures above us than there are of sensible and material below us is probable from hence, that in all the visible and corporeal world we see no chasm, no gaps. All quite down from man, the descent is by easy steps: there is a continued series of things that in each remove differ the least that can be conceived from each other. There are fishes that have wings, and are not strangers to the airy regions; and there are birds which are inhabitants of the waters, whose blood is as cold as that of fishes. There are animals so near a-kin both to birds and beasts that they are in the middle between both. Amphibious animals link the terrestrial and aquatic together. Seals live either on land or in the sea. Porpusses have the warm blood and entrails of a hog. There are brutes that seem to have as much knowledge and reason as some that are called men. Again; the animal and vegetable kingdoms are so closely joined, that between the lowest of the one and the highest of the other, there is scarce any perceptible difference. And if we go on till we come to the lowest and most inorganical parts of matter, we shall find every where that the several species are linked together, and differ in almost insensible degrees.

"Now, when we consider, on the other hand, the infinite power and wisdom of the Creator, does it not appear highly suitable to the magnificent harmony of the universe, and the infinite goodness of the architect, that the species of creatures should also, by gentle degrees, ascend upwards from us (as they gradually descend from us downwards), towards his infinite perfection? And if so, is it not probable there are far more species of creatures above than beneath us? since we are infinitely more remote from the all-perfect Creator than from the lowest of all the works of his hands?

"But here our thoughts are lost. We may conjecture a little; but we *know* nothing. However, it is enough that we *know the only true God, and Jesus Christ whom he hath sent.*"

This reflection upon *the scale of beings* is pursued at large by one of the finest writers of the age, Mr. Bonnet, of Geneva, in that beautiful work, "The Contemplation of Nature." When I first read this, I designed to make only some extracts from it, to be inserted under their proper heads; but, upon farther consideration, I judged it would be more agreeable, as well as profitable to the reader, to give an abridgement of the whole, that the admirable chain of reasoning may be preserved, and the adorable wisdom and goodness of the great Author of nature placed in the strongest light.

INTRODUCTION.

I RAISE myself up to the ETERNAL REASON; I study his laws, and I adore him. I contemplate the universe with a philosophic eye: I search into the relations which by this immense chain constitute one whole. I stop a while to examine some links of it, and, struck with those marks of power, wisdom, and goodness which I discover therein, I faintly attempt their description.

CHAP. I.

Of the first Cause.

1. TO be self-existent, endued with Almighty power, and to will with infinite wisdom, are the adorable perfections of the first cause.

The universe is undoubtedly derived from this cause. In vain do we endeavour by other means to account for it. We may every where observe order and ends, the effects of an ETERNAL SELF-EXISTENT REASON.

2. What mind can fathom the depths of this abyss? What thought can comprehend that Power which calls things that are not as though they were? God commands the universe to be: the universe is instantly produced.

A single act of his will produced the universe—the same act preserves it.

But you ask, Why is not man as perfect as an angel? You mean to say, no doubt, Why is not man an angel? You may as well enquire, Why a stag is not a man? But the existence of a stag supposes that of herbs to nourish him: Would you still further have had these herbs to have been so many men? Their preservation and increase would have depended on the earth, the water, the air, and the fire: would you presume to insist in your enquiry, Why the constituent parts of these elements were not so many dwarfs?

Confess your error, and acknowledge that every being is endued with a perfection suited to the ends of its creation. It would cease to answer that end the very moment it ceased to be what it is. By changing its nature it would change its place, and that which it occupied in the universal hierarchy ought still to be the residence of a being resembling it, otherwise harmony would be destroyed.

In the assemblage of all the orders of *relative* perfections consist the *absolute* perfection of this whole, concerning which God said, *That it was good.*

This immense system of co-existent and successive beings, is no less *one* in succession than in co-ordination, since the first link is connected with the last by the intermediate one. Present events may make way for the most distant ones. The germ which expanded itself in Sarah's womb was the preparatory cause of the existence of a great people, and the salvation of nations.

3. The heavens declare the glory of God, and the firmament sheweth his handy-work. That sublime genius, who expressed himself with such loftiness of sentiment, was nevertheless unapprized that the stars which he contemplated were in reality suns.* He anticipated the times, and first sung that majestic hymn which future and more enlightened ages should chaunt forth to the praise of the Founder of worlds.

This assemblage of vast bodies is divided into different systems, the number of which perhaps exceeds the grains of sand which the sea casts on its shores.

Each system then has its centre, either a star or sun, which shines with its own light, and round which revolve various orders of opake globes, that reflect with greater or less lustre the light they borrow from it, which renders them visible to us.

These globes, which seem to *wander* among the heavenly bodies, are those *planets*, the *principal* of

* Perhaps so.

which have the sun for the common centre of their periodical revolutions: whilst the others, which are called *secondary*, move round one principal planet, which they accompany like *satellites*, in its annual revolution.

Venus and the earth have each of them their satellite: one will undoubtedly be some time or other discovered in Mars. Jupiter has four, Saturn five, and a ring or luminous atmosphere which seems to perform the office of a number of small *moons*; being situate so far from the sun, he would have received too faint a light from it, if his satellite and ring did not augment it by reflection.

We have discovered twenty-seven planets, which at present compose our solar system; but we are not certain that there are not more. Their number has received a great increase by the invention of telescopes: more perfect instruments, and more accurate observers, may probably make farther additions to them. The satellite of Venus, discovered in the last century, gives room to hope for still greater success.

4. The comets also are now found to be planetary bodies, whose long routes our astronomers calculate, foretel their distant returns, and determine their place, appearances, and tract. Upwards of thirty of these bodies at present acknowledge the empire of our sun, and the orbits which some trace round are so extensive, that they do not complete their course till the end of a long series of years, and even many ages.

The stars are innumerable; and the constellations, which antiquity reckoned to be but few in number, amount to thousands.

If the diameter of the great orbit, which our planet describes round the sun, is more than sixty millions of leagues, yet this vast circumference vanishes into nothing, and becomes a mere point, when made use of to measure the distance of the fixed stars.

How great then must the real bulk of these luminous spots be that are perceivable by us at such enormous distance! The sun is supposed about a million of times greater than the earth, and a hundred and ten times greater than all the planets put together.

5. Whilst the planets perform these revolutions round the sun, by which the course of their years is regulated, they effect another among themselves, which determines the alternatives of their days and nights.

But how do these vast bodies remain suspended in space? What secret power retains them in their orbits, and enables them to circulate with so much regularity and harmony? *Gravity*, that powerful agent, is the universal principle of this equilibrium and these motions: it penetrates into the inmost parts of all bodies. By virtue of this force they tend towards each other in a proportion relative to their distance and bulk. So that the planets tend towards the common centre of the *system*, and they would be instantly precipitated into it, if the Creator, when he formed them, had not endued them with a *centrifugal* motion, by which they are continually kept at a due distance from the centre. Each planet, in constant subserviency to these two forces, describes a *curve* in consequence thereof. By this means the same force which determines the fall of a stone, is the ruling principle of the heavenly motions: wonderful mechanism! whose simplicity and energy give us unceasing tokens of the PROFOUND WISDOM of its AUTHOR.

The globe of earth, which is externally divided into lands and seas, nearly level in their surfaces, is formed within, at least to a certain depth, of *beds* of heterogeneous matter, that are almost parellel, more or less dense, and of a finer or coarser texture.

The surface of the earth abounds with great inequalities. In one part of it we behold vast plains intersected by hills and vallies. In another long chains of mountains, which lift their frozen heads to the clouds, and betwixt them deep vallies. From the bosom of these mountains rivers spring, which, after having watered divers countries and produced ponds and lakes in several places by enlarging their beds, at length discharge themselves into the sea, and restore to it what it had lost by evaporation.

6. The sea presents us with islands scattered round its coasts, with sands, rocks, currents, gulphs, and storms, and with that regular and admirable motion whereby its waters rise and fall twice in twenty-four hours.

The lands and seas are every where replenished with plants and *animals*, whose infinitely varied species resort together in every place. Men divided into nations, peoples and families, cover the surface of the globe. They fashion and enrich it by their various labours, and build habitations from pole to pole, corresponding with their manners, genius, soil, climate.

A rare, transparent, elastic substance encompasses all parts of the earth to a certain height: this substance is the atmosphere, the repository for the winds, the immense reservoir of vapours and exhalations, which being sometimes collected into clouds of a greater or lesser consistence, adorn our element by their forms and colours, or astonish us by their flashes and violent noise, and at other times melting into dews, mists, rain, snow, hail, yield back to the earth what was exhaled from it.

7. The moon, the nearest to the earth of all the planets, is that we have the best knowledge of. Its globe, which is about five-and-forty times less than ours, always appears to us with the same aspect, be-

cause it performs its revolution precisely in the same space of time that it revolves round the earth.

It has its gradual and periodical increase and decrease of light, according to its position with respect to the sun, which enlightens it, and to the earth, whereon it reflects the light of that sun.

The disk of the moon is externally divided into *luminous* and obscure parts: the former seems analogous to lands on our globe, and the latter to our seas.

In the luminous parts there have been observed some places brighter than the rest, which cast a shade from their side, which has been measured, and the tract ascertained. These parts are mountains much higher than ours, in proportion to the size of the moon, and whose tops the sun has been seen to gild when that planet is *quartered*, the light descending by little and little to the foot of these mountains, they appear at that time entirely bright. Some are by themselves, others form very long tracts.

Venus has, like the moon, her spots and mountains: so have Mars and Jupiter. Those in Jupiter form large belts, which make considerable motions, like the oceans overflowing the lands, and afterwards leaving them dry on his retreat.

Mercury and Saturn are little known to us, the first because it is too near the sun, the second because it is at too great a distance.

Lastly, the sun himself has spots, which seem to move regularly, and whose size equals, and very often exceeds, that of such as are seen in the greatest planets.

8. Pure spirits, immaterial and intelligent substances, extensive and solid substances; mixed beings, formed

by the union of an immaterial substance and a corporeal, are the three general classes of beings which we have any conception of in the universe.

In the universe all is combination, affinity, connexion. There is nothing but what is the immediate effect of somewhat preceding it, and determines the existence of something that should follow it.

The divine mind has so closely connected every part of his work, that there is not one which has not a relation to the whole system. A mushroom, a mite are as essential parts of it as the cedar or elephant.

So that those minute productions of nature, which unthinking men judge to be useless, are not mere particles of dust on the wheels of the machine of the world; they are small wheels intermixed with the greater.

There is nothing then by itself: every being has an activity peculiar to it, determined by the rank appointed for it in the universe. A mite is a very small moveable creature, which acts in concert with others, whose activity extends to much greater distances. The spheres thus enlarging themselves more and more, this amazing progression rises by degrees from the vortex of amber to the solar vortex; from the sphere of a mite to that of an angel.

9. The elements act reciprocally on each other, according to certain laws which result from their relations: and these relations unite them to minerals, plants, animals, and to men. This last, as the principal trunk, spreads its branches all over the globe.

These species and individuals have relation to the bigness and solidity of the earth: the solidity and size of the earth have relation to the place she occupies in the planetary system.

The sun, gravitates on the planets, the planets on the sun, and on each other; all gravitate on their neighbouring systems: these on more distant ones;

and the balance of the universe remains in equilibrio, in the hands of the ANTIENT OF DAYS.

The human soul, by being united to an organized body, maintains an intercourse with all nature.

From these general principles proceeds the connection of causes and effects, of effects and causes.

From hence also arises that indissoluble union which forms, of past, present, future, and eternity, one entire individual whole.

The beauty of the world is founded in the harmonious diversity of the beings that compose it, in the number, extent, and quality of their effects, and in the degree of goodness arising therefrom.

CHAP. II.

Of the relative Perfection of Beings.

1. TERRESTRIAL beings may naturally be ranged under four general classes:

I. Brute and inorganized beings.
II. Organized and inanimate beings.
III. Organized and animate beings.
IV. Organized, animate, and reasonable beings.

All beings are perfect, considered in themselves; they all answer one end. The determinations or qualities proper for each being, are the means relative to this end. If these determinations should change, they would no longer have a reference to their end, and there would be no more wisdom.

But those means which are of a more exalted nature answer a nobler end. The being appointed to fulfil this end, is enriched with proportionable faculties.

Beings whose relations to the whole are more varied, more multiplied, and more copious, possess a higher degree of relative perfection.

As there are two general classes of substances, bodies and souls, there are likewise two general classes of perfection, the *corporeal* perfection, or that which is peculiar to bodies; and the *spiritual* perfection, or that which is peculiar to souls.

These two perfections are reunited in every organized animated being, and they correspond with one another.

From their reunion proceeds that *mixed* perfection which answers to the rank every being holds in the system.

2. Of all the modifications of matter, the most excellent is organization.

The most perfect organization is that which produces most effects, with an equal or smaller number of dissimilar parts. Such amongst terrestrial beings is the human body.

An organ is a system of solids, whose structure, arrangement, and action, have motion for their ultimate end, either intestine or loco-motive, or feeling.

A being, which is barely formed by a repetition of similar parts, enjoys the lowest degrees of corporeal perfection. Such probably is the *atom* or *elementary particle*.

The faculty of generalizing ideas, or abstracting from a subject what it has in common with others, and expressing it by arbitrary signs, constitutes the highest degree of spiritual perfection; and therein consists the difference between the human soul and the soul of brutes.

The soul which is only endued with sense occupies the lowest degree in the scale. This perhaps is the perfection of the soul of the muscle.

3. The reciprocal action of solids and fluids is the foundation of the terrestrial life.

To nourish ourselves, to *grow* by our food, to beget individuals of our own species, are the principal ends of the terrestrial life.

If the action of the organs is not accompanied with a sense of this action, the organized being enjoys only a *vegetative* life. Such is the case of the *plant.*

If the action of the organs is joined with a sense of that action, the organized being enjoys a *vegetative* and *sensative* life. This is the condition of the *brute.*

Finally, if reflection is joined to feeling, the being enjoys at the same time a *vegetative, sensative* and *reflective* life. It is man alone, upon earth, that unites these three kinds of life in himself.

The corporeal and intellectual faculties may be carried to so high a pitch of perfection, in the most exalted order of mixed beings, that we are able to form but faint ideas of them.

4. Between the lowest and highest degree of corporeal and spiritual perfection, there is an almost infinite number of intermediate degrees. The result of these degrees composes the *universal chain.* This unites all beings, connects all worlds, comprehends all the spheres. One **SOLE BEING** is out of this chain, and that is **HE** that made it.

A thick cloud conceals from our sight the noblest parts of this immense chain, and admits us only to a slight view of some ill-connected links, which are broken, and greatly differing from the natural order.

We behold its winding course on the surface of our globe, see it pierce into its entrails, penetrate into the abyss of the sea, dart itself into the atmosphere, sink far into the celestial spaces, where we are only able to descry it by the flashes of fire it emits hither and thither.

But notwithstanding our knowledge of the chain of beings is so very imperfect, it is sufficient at least to inspire us with the most exalted ideas of that amazing and noble progression and variety which reign in the universe.

5. There are no sudden changes in nature; all is gradual, and elegantly varied. There is no being which has not either above or beneath it some that resemble it in certain characters, and differ from it in others.

Amongst these characters which distinguish beings, we discover some that are more or less general. Whence we derive our distributions into classes, genera, and species. But there are always between two classes, and two like genera, *mean* productions, which seem not to belong more to one than to the other, but to connect them both.

The polypus links the vegetable to the animal. The flying squirrel unites the birds to the quadruped. The ape bears affinity to the quadruped and the man.

But if there is nothing cut off in nature, it is evident that the distributions we make are not her's. Those we form are purely nominal, relative to our necessities and the bounds of our knowledge. Those intelligences which are superior to us, discover perhaps more varieties between two individuals which we range under the same species, than we do between two individuals of distant genera.

So that these intelligences see the scale of beings all composing one single consequence, which has for its first term an atom, and for its last the most exalted seraph.

We may then suppose in the scale of our globe as many steps as we know there are species. The eighteen or twenty thousand species of plants which compose our herbals, are therefore eighteen or twenty thousand steps of this celestial ladder.

And there is not a single plant amongst these, which does not perhaps nourish one or more species of animals. These animals harbour or provide nourishment for others in their turn. They are so many little worlds comprized in others that are still smaller.

Simple produces compound. The molecule forms the fibre, the fibre the vessel, the vessel the organ, the organ the body.

The scale of nature then is constructed by passing from that which composes it, to that which is composed by it, from the less perfect to the greater.

But while we view it in this light, and in a very general manner, we are not to forget that our method of conception is not the rule of things. We are only to take a transient survey of the exterior parts of beings.

CHAP. III.

A general View of the gradual Progression of Beings.

1. FROM the immutability of species amidst the perpetual motion that reigns in the universe, is deduced the indivisibility of the first principles of bodies: and the indivisibility of these principles would demonstrate the simplicity of their nature, if God had not power to render the highly compounded particles incapable of separation.

The nature of elementary atoms, their forms, relative proportions, and the manner whereby they effect the formation of bodies, are branches of knowledge that surpass the reach of the human mind.

So that we cannot determine whether there are as many species of elements as of bodies; or whether the same elementary particles, variously combined, give birth to different compounded species.

We are likewise ignorant what it is that essentially distinguishes one body from every other; those we call *essential characters,* are only the ultimate result of the first principles.

O how interesting would the sight be, were we permitted to penetrate into these principles! A new world would disclose itself to our view; nature then become transparent, would no longer conceal her way from us: her laboratories and workshops would then be thrown open. Here we should see her collecting the principles of metals; there behold her preparing the colour of the rose. Farther, we might trace her footsteps into the wonders of light and electricity. In other places should observe her sketching the out-lines of a plant or animal. Astonished at the sight of this admirable work we should never be weary of contemplating the infinite diversity of preparations, combinations, and motions, by which it is insensibly brought to its perfection.

Ye celestial spirits who assisted at the creation of our world, you enjoy these pleasures! Being more favoured than us by the MASTER of nature, you penetrate into what escapes our notice, and see with what difficulty we creep from one truth to another, as we observe the efforts of an ape to imitate a man.

2. Observe three principal kinds of compositions in terrestrial bodies. 1 That of *fluids*. 2. That of *rude* or *un-organized solids*. 3. That of *organized solids*.

The first genus, which is the most simple, seems to consist in a bare contact of homogeneous particles, which tend towards each other; but the least force divides them.

The second, which is more compounded, is formed of the union of different particles into a solid mass.

The third, still more compounded, is formed of the intermixture of an infinite number of parts, some fluid, and others solid.

3. The small resistance which fluids make to the force that divides them, their inclination to a level, the quickness and ease wherewith they move, penetrate, and separate solids, serve to indicate that they are of all bodies the most simple, subtle and active.

Fire seems to be a fluid which unites these qualities in the most eminent degree. It is evident from a number of experiments, and particularly from those made by *electricity*, that fire is a fluid diffused into all bodies, in various proportions. Sometimes it barely fills their pores; at others, is intimately united to their constituent parts, and composes inflammatory matter.

Air and *water* are likewise contained in the composition of a prodigious number of matters of different kinds. Sometimes they seem to change their nature, and to undergo various transformations; but these transformations are only imaginary. They resume their primitive state, as soon as the causes which obscured them cease to act.

4. Pure earth is the base or foundation in the composition of solids. The chymist meets with it in every body he analyses. Being fixed and unalterable, it will resist the most violent fire; and this immutability of elementary earth, by convincing us of the simplicity of its nature, shews likewise that it is the first step of the scale of inactive solids.

From a mixture of pure earth with oils, sulphurs, salts, &c. proceed the various species of more or less compounded earths, which are the proper nourishment of one part of organized bodies.

Bitumens and *sulphurs,* which are chiefly formed of inflammable matter and earth, seem to lead us from pure earth to metallic substances, in which we discover the same essential principles, only differently combined.

The inalterability of gold from the most violent fire, its malleability, and prodigious ductility, equally prove the homogeneousness, extreme fineness, and strict union of its parts.

Other metals are ranged after gold, according to the order of their composition, or the stronger or weaker combination of their principles. Platina immediately follows gold: and silver that. Silver also resists the action of fire; but is less malleable and ductile than gold, and dissoluble by a much greater number of dissolvents.

Copper appears after silver, and has a great affinity to that metal. It is itself succeded by tin, lead, and iron.

Those compounds which differ from metals only by their not being malleable, bear a great resemblance to them, and are called *demi-metals.* Such are *antimony, bismuth, spelter.*

Vitriols, produced by the union of metallic particles with a coagulated acid, seem to be the passage from metallic substances to *salts.*

Salts, which always affect determinate and constant figures, indicate thereby the invariableness and simplicity of their principles, whose fundamentals are water and earth.

When they are dissolved by water, or volatilized by air, they become one of the principal causes of the growth of vegetables, as they are of *fermentations,* whose effects are so various and extensive.

The regularity and uniformity of the different kinds of crystallization, sufficiently prove that they are to be attributed to salts, which being dissolved and conveyed by a liquid, and united to foreign matters, compose these pyramidal masses.

Stones, whose species are so numerous, present us with masses of every form, colour, size, and consistence, according to the diversity of liquids, earth, sulphur, metallic parts, salts, places, and other circumstances which contributed to their formation.

Some of them are perfectly transparent; and these seem to be the most simple. Others are more or less opake, as their principles are more or less heterogeneous, or more or less mixed.

5. The apparent *organization* of *leafed* stones, or such as are divided into layers, as slates; that of fibrous

stones, or those composed of filaments, as the amianthus; seem to constitute the passage from rough to organized solids.

We must however allow, that this transition is not so happily effected, as those we observe in divers other classes of terrestrial beings.

Organized solids are divided into two general classes; *vegetable* and *animal.*

It is not easy to determine precisely the distinction between these two classes. We cannot clearly discern where the vegetable terminates, or the animal commences.

Neither the greater or less degree of simplicity in organization, nor the method of production, nourishing, increasing, and multiplying, nor the *locomotive* faculty, sufficiently enables us to distinguish between these two orders of beings.

There are some animals whose structure appears as simple as that of plants.

What the seed and germ are to the plant, the egg and embryo are to the animal.

The plant and animal increase in equal proportion by an insensible expansion occasioned by nutrition.

The matter received in both of them by inward susception, is there subject to analogous preparations. One part serves as a clothing to the essence of the plant or animal; the rest is evacuated.

There is in plants as well as animals a distinction of sexes; and this distinction in them is followed by the same essential effects that accompany the latter. Several kinds of animals multiply by slips and sprigs; and there are some, that, like plants, pass their whole lives without changing their situation.

If there is any one character peculiar to the animal, it is that of being furnished with nerves.

6. The plant which seems to occupy the lowest place in the scale of vegetables, is a small unformed mass, in which the eye can only perceive a kind of marbling, without any distinct part. This plant is the truffle, the seeds of which are discovered by the microscope.

At a small distance from these is the numerous family of mushrooms and agarics, which would be taken for different kinds of excrescenses, were it not that the eye, by the assistance of a glass, can discover flower and seeds in their folds or cavities.

Liverworts, equal in the number of their species to mushrooms, nearly resemble them. They cleave to the surface of stones, dry wood, trees, &c. sometimes like brown spots, at others in pieces of a circular form, of a grey or yellow colour, composed of small shells or nobs, or notched like fringe, lace, &c. The seeds are contained in small capsules, invisible to the naked eye, as are likewise the flowers.

Mosses seem to be a species between the mushrooms and liverworts; they delight in shade and moisture, and cling to various sorts of bodies. The filaments which issue from them are often of a cotton-like nature, and bear flower and seeds.

7. Plants are of three very distinct sorts:

The first, which are for the most part of a small size, delicate constitution, inactive, and abounding in humours, live but a short time; a year is commonly the term of their life.

The second, which are for the most part of a gigantic size, robust constitution, hard, and not so full of humours, live many years, and even for several ages.

The third bear a mean proportion between the first and second.

Herbs are the first, *trees* the second, and *shrubs* the third.

These three kinds, which are spread over the face of the earth, live promiscuously therein; but there exists, in the different classes, an almost infinite diversity of sizes, forms, colours and inclinations.

They all in common pass their lives in a state of immoveableness. Fixed to the earth by various sorts of fibres, they derive their principal nourishment from it; and with them to live is to expand themselves.

8. The *roots, stalks, branches, leaves, flowers,* and *fruits,* comprize all that is most remarkable in the external parts of plants.

The *roots,* by means of their different kinds of *hinges, tuberosities,* and *ramifications,* keep the plant fixed to the earth, while their pores imbibe an exceeding fine slime, which the water liquefies and carries with it.

From the root springs the stalk, to which the plant partly owes its strength and beauty. Being sometimes shaped like a pipe, it is fortified with knots skilfully disposed. As it is sometimes too weak to support itself, it contrives means to twist itself about a solid prop, or to fasten to it by means of the little *hands* it is furnished with. Otherwise it appears a strong pillar, bears its proud head aloft in the air, and braves the efforts of storms and tempests.

The *branches* shoot forth, like so many arms, from the trunk and stalk, on which they are distributed with great regularity. They are divided and sub-divided into many small boughs, and the sub-divisions observe the same order as the principal divisions.

The *leaves,* that charming ornament of plants, are disposed round the stalk and branches with the same symmetry. Some are *simple,* others *compounded,* or formed of various foliage. One sort is plain, another indented. Some of them are very thin, others hard, soft, plump, smooth, rough, or hairy.

The *flowers*, whose enamel is one of the principal beauties of nature, are not less diversified than the leaves: some have only a single leaf, others several. Here it appears like a large vessel opening itself gracefully; there it forms a grotesque figure in imitation of a muzzle, head-piece, or cowl. Farther still, it is a butterfly, a star, a crown, a radient sun. Some are dispersed on the plant without any art; others compose nosegays, globes, tufts of feathers, garlands, pyramids. The greater part of them are furnished with one or more cups, sometimes simple and plain, at others consisting of several pieces.

From the centre of the flower proceeds one or several little pillars, either smooth or channelled, rounded at top, or terminating in a point called *pistils*, which commonly encompass other smaller pillars, called *stamina.* These carry on the upper part of them a sort of small bladders, full of exceeding fine powder, every grain of which, viewed through a microscope, appears of a very regular figure, but varied according to his species. In some they are small smooth globes, in others they are thick set with prickles, like the covering of a chesnut; and sometimes they resemble small prisms, or some other regular body.

But how shall we express their fineness, the lively appearance, delicacy, and variety of shadowings which accompany, in many species of flowers, the sweetness and agreeableness of the perfume?

The flowers are succeeded by the *fruits* and seeds: magnificent decoration! prescious riches, which repair the losses occasioned to plants by the intemperateness of seasons, and the necessities of men and other animals!

All fruits and seeds have this in common, they enclose under one or more coverings the germ of the future plants. Some have only such coverings as immediately infold the germ, whose outside is of the strongest contexture; and among these, there are some that are provided with wings, tufts, or plumes of feathers, by means of which they are conveyed in the air or water, by which they are transported and sown in different parts. Others are better clothed, being lodged in sheaths or pods, enclosed in a kind of box, having one or more partitions. A third sort, under a most delicious fruit, which is rendered still more agreeable by its beautiful colour, contain a stone or kernel. others are enclosed in shells, which are either armed with prickles, abound with a bitter juice, or adorned with fine hair.

The outside of fruits and seeds do not afford less variety than the leaves and flowers; there is hardly any figure whatever which they do not furnish a representation of.

9. The inside of plants is composed of four orders of vessels, viz. the *ligneous fibres, utriculi,* or *little bags,* the *proper vases,* and the *trachea,* or *air vessels.*

The *ligneous fibres* are very small channels deposited according to the length of the plant, and consist of little pipes placed near each other. Sometimes these vessels are parallel, and at others are separated, leaving between them intervals, or oblong spaces.

These spaces are filled by the *utriculi,* a kind of membranous bladders, horizontally disposed, and which communicate with each other.

The *proper vases* are a kind of ligneous fibres which principally differ from the rest by their juice, which is of a deeper colour, or thicker.

In the middle of them, or round a great number of ligneous fibres, are some vessels which are not so narrow, composed of a silvery elastic blade, formed spirewise, like a spring: these are *arteries*; they seldom contain any thing but air.

These four orders of vessels, which are dispersed through all the parts of the vegetable, in proportion to the functions of each, compose, at least in trees and shrubs, three principal beds, the *bark*, the *wood*, and the *pith*.

The *bark*, or *rind*, which is the outer covering of plants, and is smooth, even, and shining in some, and rough, channelled, and hairy in others, is formed of the widest fibres, that are the least pressed together, and which admit within them the most air.

The *wood*, which is placed under the rind, has narrower and more contracted pipes, its utricles less replenished or dilated; and this only has arteries.

The *pith*, which is situated at the heart of the plant, is little more than a collection of utricles, which are greater and more capacious than those of the bark and wood: they diminish and dry up as the plant advances in age.

The simplicity of the organization of vegetables is the principal source of their different methods of multiplication.

A plant pushes out buds from all points of its surface; these buds themselves are plants; being cut and laid in the ground they take root there, and become entire plants, like that of which they were before only a part.

The smallest branch or leaf may give birth to such a whole plant.

Suckers taken from different plants, and ingrafted in the stalk or branches of another plant, incorporate themselves with it, and being united thereto, form one organical body.

10. The timorous *sensitive* plant flies the hand that approaches her; she closes herself again with the utmost speed; and this motion, bearing so great a resemblance to that of animals, seems to constitute one of those connections whereby the *vegetable* and *animal kingdoms* are united.

A little above the sensative, in a kind of calix, at the bottom of the water, is a small body, exactly resembling a flower. It draws back and entirely disappears when I offer to touch it. It comes out of the calix, and opens itself on my retiring to a distance from it.

While I was endeavouring in vain to account for this, I discovered, by the side of it, another body of the same form, but larger, and not lodged in an inclosure. It was supported by a small stalk, whose lower extremity joined to a plant, whilst the other, inclining towards the ground, was divided into several little branches.

I immediately believed it to be a *parasite* plant; and, in order to be more fully convinced of it, I cut it in half between its two extremities.

It soon sprouted out again, and appeared the same as before. I stood awhile to consider it. I saw the little branches move, and extend themselves to several inches in length. They are extremely fine, and spread themselves on all sides.

A little worm came and touched one of these branches; it presently twisted itself about the worm, and by contracting itself, brought it to the upper extremity of the stalk: there I perceived a small aperture, which enlarged itself in order to receive the worm. It was received into a long cavity that encloses the stalk, being there dissolved and digested before my eyes: I afterwards saw the remainder go out again at the same opening.

The next moment this singular production separated itself from the plant, and began to walk. The branches, after having performed the office of arms, are likewise employed by it instead of legs.

After having made these observations, I could not help acknowledging, that what I took for a parasite plant was a real animal. I then took a view of the piece I had cut off from it, and perceived, to my surprise, that it had grown, and was become a complete one like the other.

But my surprise was greatly increased when, at the end of some weeks, I found these animals were transformed into two small very bushy trees.

From the trunk, which I knew to be the body of the animal, sprung several branches on all sides of it: from these branches smaller ones sprouted forth, and from those, smaller still: they all move different ways, and stretch out their branches, while the trunk continues fixed to a prop. This surprising assemblage forms only one entire body; and the nourishment it receives by one of its parts is successively communicated to all the rest. In short, this collection of bodies divides itself; each piece separates itself from the others, and lives distinctly from them.

Amazed at these wonders, I part one of these animals length-wise, about the middle of the body, I am presently in possession of a monster with two heads.

I repeat the operation a great many times on the same subject, and by this means I give birth to a hydra, more astonishing than that of *Lerna*.

I part several of these animals transversely, and lay the separated pieces end to end; they graft or unite themselves to each other, and compose only one entire animal.

To this prodigy I find a new one succeed. I turn one of these insects, as we do a glove, putting the outside within, and *vice versa*; he does not suffer the least alteration from that; he lives, grows, and mutiplies.

These animals, which multiply by slips and shoots, that we engraft and turn inside out, are polypus's.

They are of very different species: many of them never shift their place: some divide themselves lengthwise, and thus make very pretty nosegays, whose flowers are in clusters.

11. There is a wonderful variety in the construction of animal machines. There are some whose number of parts is very small; others, on the contrary, are very much compounded. In some there are only two or three pieces alike, others exhibit to us a much greater number. In short, the same parts are differently disposed or combined in different machines.

The perfection of the machines in nature consists, as in those of art, in number of parts and diversity of effects. That is accounted the most perfect which, with the smallest number of parts, produces the greatest variety of effects.

But there is, with respect to ourselves, a considerable difference between the natural and artificial machines; for whereas we may judge of these by an exact comparison of their strength and produce, we can only form our opinion of the others by their consequences.

After this manner we are enabled to judge of the perfection of the human body, from the diversity and extent of the operations of man, rather than from an inspection of his organs, of which we have only a partial view. And if corporeal perfection corresponds with spiritual, as there is reason to believe it does, man, as he is superior to other animals by understanding, so he likewise is by organization: whence we may infer, that those animals, whose structure most nearly resembles that of men, ought to be considered as the most elevated in the scale.

12. Of all animals that are known to us, the polypus is one whose structure seems to be the most simple, and to come nearest that of plants. This extraordinary animal seems to consist altogether of stomach. His body and arms are composed of one and the same bowel,

whose composition is perfectly uniform. The best microscopes only discover in them an infinite number of small grains, which are tinged with the nourishment the animal feeds upon.

Can these grains be so many utricles? Can they receive the aliment by immediate conduits, prepare it and transmit it to other vessels appointed to convey it into the channels of circulation? Is there a circulation in the polypus?

The different kinds of vessels which the first conjecture supposes, and which their fineness or transparency may render invisible to us, must be lodged in the thick part of the texture of the polypus. We are induced to think so from the experiment of turning it inside out, which being effected, does not cause any change in the vital functions.

But of what service can that property be to the polypus, which it cannot make use of without the assistance of man? I mean, the operation of turning the inside outwards.

I answer, that this property is one of the consequences of an organization peculiarly necessary to the polypus. The Author of nature never intended to create an animal capable of being turned as we do a glove; but he designed to form an animal whose principal viscera were lodged in the thickest part of the skin, and which had power, in a certain degree to escape various accidents to which the nature of its life unavoidably exposed it. Now, what naturally follows from this organization is the being enabled to endure this shifting without occasioning its death.

13. Those animals whose structure appears less simple than that of the polypus, multiply like him by slips.

These *worms* have a stomach, intestines, heart, arteries, veins, lungs, and organs of generation. If we look narrowly into the circulation of their blood, we shall perceive its continuance with the same regularity in all those parts which have been separated from the rest by cutting.

These worms bring us to treat of *insects*.

14. Here we are introduced into a kingdom of *animals*, the most extensive and diversified of any on the surface of the globe. That province of this vast empire which is seen on the surface of vegetables, is sufficient of itself to attract the curiosity of a traveller, either from the prodigious number of its inhabitants, or the singularity and diversity of their forms.

These are pigmies, the greatest part of which are so minute, as not to be distinctly seen without the help of a microscope: they bear the general name of *insects*, and this name was given to them on account of the *incisions* of various depths, by which the bodies of several of them are divided.

The character which seems essentially to distinguish insects from other animals is, that they have no bones. The analogous parts with which some species of them are provided, are placed on the outside of their bodies, whereas in other animals the bones are always on the inside.

Life, in insects, does not result from a mechanism as compounded as in the animals of a larger size: in them the number of different kinds of organs is smaller; but some of these organs seem more multiplied.

Considered in their exterior form, insects may be divided into two classes. The first comprehends insects *improperly so called*, whose body is continued: these bear the general name of worms. The second class comprehends insects properly so termed, whose body is divided by certain incisions or contractions.

In the greater part of insects of this class, the incisions separate the body into three principal parts; the *head*, the *stomach*, the *belly:* this division has a relation to that observed in great animals. Some of the insects of the first class are without legs; others are furnished with them. All the insects of the second class have legs; but some are winged, others not.

There is such a diversity in insects, that it may be questioned, if there is not united in them every variety to be met with throughout the animal world. And what renders this variety still more surprising, is, that it does not extend merely to the whole species, but likewise to individuals. The same insect has, at one time, organs that are not to be found in him at another. The same individual which, in his youth, belonged to the first class, in a more advanced age, takes up his rank in the second. From thence arise the difficulties attending a proper distribution of these little animals.

15. The bodies of almost all insects are formed of a collection of *rings,* set in each other; which, by contracting or dilating, lengthening or shortening, contribute to all the motions of the animal.

The *head,* in many species, changes its form in an instant. It contracts and dilates itself, lengthens and shortens, appears and disappears, at the pleasure of the insect. The flexibility of its folds enables it to make these motions. In other species, the head is in one constant position, and bears a greater resemblance to that of the larger animals, by the hardness of its covering, which is scaly.

The *mouth* is sometimes discovered to be a simple circular aperture: but it is generally furnished with hooks, or a kind of pick-axe; with *teeth,* or two indented shells, which they move horizontally; with a *trunk,* a very compact instrument, which serves to extract and liquify, and raise up alimentary juice; or with a sting, which is an organ analogous to the trunk, and endued with the same essential functions.

Several species have two of those instruments united in them; sometimes the teeth and the trunk, and sometimes the trunk and the sting. Many species of insects are deprived of the use of sight. With them the feeling, or some other sense, supplies the defect of eyes.

The eyes of insects are of two kinds: the *smooth* ones are always few in number; the *rough* commonly amount to several thousands, and are fixed on the sides of the head, in the form of two semicircular masses. In both of them they are utterly immoveable; and their number compensates, in some measure, the want of mobility: it is, therefore, less a mark of perfection than of imperfection. Many species have, at the same time, two smooth eyes, and two rough ones.

. Hearing seems to be denied to insects: at least, the existence of this sense in them, is very doubtful.

The case is not the same with respect to smelling. Divers insects have it in an exquisite manner; but the seat of it is not known. May it not be situate in those two moveable horns called the antennæ, whose use we are yet unacquainted with?

The *legs* of insects are *scaly* and *membranous.* Those are moved by the assistance of divers articulations; while these, which are more pliable, are turned every way without difficulty. These two sorts of legs are often united in the same worm. Some of them have several hundred legs; but do not, on that account, walk faster than such as have only six.

The *wings,* which are two or four in number, are sometimes formed of a simple, and more or less transparent, gauze, and sometimes covered with little scales, differently figured; in some they are composed of feathers, as in birds; in others, they are covered, or enclosed in cases. In many species, the male is winged, and the female not.

On the sides, or extremities of the body, are little oval apertures, shaped like the ball of the eye, and susceptible of the same motions. These are so many mouths, for the purpose of respiration.

16. The interior part of insects contains four principal viscera; the spinal marrow, the *intestinal bag*, the heart, and the tracheal arteries.

A blackish thread, which is extended the whole length of the belly, from the head to the hinder part, and knit together at certain distances, is the *spinal marrow* of insects, or the principal trunk of the *nerves*.

The *knots* placed from one space to another, seem so many particular *brains*, appointed to distribute the nervous strings to the neighbouring parts; from the action of which the feeling and motion proceed. The first of these knots constitutes the *brain*, properly so called.

On the medullary thread is placed the *intestinal bag*, which is equal to it in length. It is a long gut, in which are contained the *œsophagus*, the *stomach*, and *intestines*.

Along the bag, and parallel to the intestinal bag, there runs a long and thin vessel, in which may be perceived, through the skin of the insect, alternate contractions and dilations. This is the heart, or that part which performs the functions of it.

The arterial vessels of insects perfectly resemble those of plants. There is in every part of them the same structure, colour, elasticity, destination, and dispersion, through the whole body.

17. Worms, whose bodies are lodged in a crustaceous, or stony pipe, seem to constitute the connection between insects and shell-fish.

There are, notwithstanding, some shell animals, whose structure, with respect to its simplicity, seems to vie with that of the polypus.

Of this number is the *pond muscle*, wherein we can discover neither spinal marrow, arteries, veins, nor lungs.

Does the scale of nature branch out as it advances? May insects and shell-fish be two parallel branches of this great stem? May the *frog* and the *lizard*, which bear so near a resemblance to insects, be a ramification of them? We are not able, at present, to answer these questions.

Such is the gradation between beings, that they often differ from each other by slender shadowings; and such is the narrowness of our capacities, that none but the plain, and more striking marks, attract our notice.

18. The agreeable diversity in the figures of shells, helps us to judge of the variety subsisting in the organization of those animals who are the inhabitants and architects of them. Some consist of one entire piece; others, of two, or more. Some are formed in imitation of a *trumpet*, a *screw*, a *tiara*, a *dial*. Others resemble a *helmet*, a *club*, a *spider*, a *comb*. In this, it is a kind of fleshy case; in another, it is a ship, wherein the sailor is, at the same time, rudder, mast, and sail.

Animals that have shells, and insects with scales, seem to have an affinity to each other by a common character; both of them have their bones placed on the outside. We may, in effect, consider the shell as the bone of the animal which occupies it; since he brings it into the world with him, and adheres to it by different muscles.

But it is certain, most shells are formed of the stony juices, which transude from the pores of the animal.

The bones, as well as the shells, of insects, grow, and are nourished, by vessels which pass through their substance.

Shell-fish form two great families; that of the *conchæ*, or larger kind, whose shell is made up of two, or several pieces; and that of *snails*, whose shell consists of one single piece, turned, for the most part, spirally.

The structure of the first seems much more simple than that of the last. The conchæ have neither head, horns, nor jaws; one can only observe in them air-vents, a mouth, an anus, and sometimes, a sort of foot. The greatest part of *snails*, on the contrary, have a head, horns, eyes, a mouth, an anus, and a foot. The round and fleshy *head* is at the anterior, and upper part of the animal. It contains a brain, composed of two little globes, whose apparatus is of such a moveable nature, that it is transferred from the hinder to the fore part, at the pleasure of the snail. The *horns*, which are two, or four, in number, placed on the sides of the head, are a kind of pipes, susceptible of various motions, and which the animal can draw into his head by the help of a muscle; which the Grand Observer has ordained to perform the functions of the *optic nerve*. In some species of snails, the *eyes* are placed at the extremity of the horns, as at the end of the shank of a pair of spectacles. In others, at the base, or towards the middle. They are black and brilliant; pretty much resembling the form of a very small onion. We can only discover their *tunic*, which is called the *uvea*; but they have the three humours belonging to our eye. The *mouth*, which is commonly a small chink, like a furrow, is furnished, in many species of them, with two cartilaginous jaws, placed on each other, whose inequalities, or clefts, perform the office of *teeth*: some species have real teeth, like those of a sea-dog, which are extremely small.

The shell-fish that have no jaws, have a fleshy, or muscular pipe, which supplies the place of a *snout*.

Snails are not provided with feet; but they have one foot, of a particular make, which is nothing more than a collection of a great number of muscles, whose motions imitate those of the waves of the sea. A pretty thin membrane lines the inside of the shell, and sometimes the outside. It is a kind of *mantle*, furnished with trachea, or air-vents, which separate the air from the water; at the origin of which are perceived, little *gills*, destined to the same uses. The *heart*, which is situated near the surface of the body, has a sensible motion, whereby it raises and falls alternately. In the conchæ, it is underneath the stomach.

19. Animals with shells bear an affinity to fishes. *Reptiles* seem to take place between, or next to them; being united to shelled animals by the *slug*, and to the fishes by the *water-serpent*.

In reptiles, animal perfection begins to increase in a sensible manner. The number of their organs, their conformation and exercise, give them, on this account, a greater analogy with the mechanism of those animals we esteem the most perfect. The organs of vision, hearing, and circulation, furnish examples sufficient to indicate this. This analogy is augmented in fishes.

The *eel*, by its formation, and *creeping fishes*, by their method of moving, connect fishes with the water-serpent.

20. Fish, like reptiles, are for the most part covered with *scales*, whose figure, and rich colours, help to make a distinction between the species.

There is a great variety in the form of fishes. Some are long and slender; others are broad and short. We see among them, flat, cylindrical, triangular, square, and circular ones. Some are armed with a great *horn*. Others wear a long *sword*, or a kind of *saw*. A third sort are furnished with *pipes*, through which they throw out the remainder of the water they have swallowed. Wings are to birds, of the same use as *fins* to fishes.

Some have two, or three; others have a greater number. The *head* of fishes, like that of reptiles, is joined close to the body. The mouth, which is commonly furnished with two or more rows of teeth, is sometimes placed on the back, as are the eyes. The *lungs*; which are formed of several blades, or vascular leaves, are often placed at the surface of the body. They are known by the name of *gills*. But, let us avoid anatomical descriptions, which would carry us too far. We shall now confine ourselves to some of the principal varieties, and to the sources of those relations that are more striking.

21. I see the flying-fish dart itself into the air from the bottom of the water, having fins resembling the wings of a bat. Herein it has an affinity to birds. But I see a great animal advancing towards the sea-shore, having a head and fore-part like a lion, and the hind-part resembling that of a fish. It has no scales; and is borne on two paws, that have toes with fins to them. 'Tis called the *sea-lion*. He is followed by the *sea-calf*, and the *hippopotamus*, or sea-horse, and by all, in general, of the *cetaceous* kind. The *crocodile* and *tortoise* present themselves to my view in their turn; and I now find myself among quadrupeds. Without presuming to account for the ways of nature, we will, at present, place birds between fishes, and four-footed animals. In this order, *aquatic* birds are ranged immediately under the flying-fish. *Amphibious* birds, or such as live both on land, and in the water, will occupy the scale next in course; and, by this means, open a communication between the terrestrial, aquatic, and aërial regions.

To this new mansion there is added a new decoration. To scales succeed feathers, which are closer compacted, and more varied: a bill takes place of teeth; wings and feet are to them instead of fins; lungs formed within, and a different structure, cause the gills to disappear: a melodious song follows a profound silence. Between the *cormorant* and *swallow*, the *partridge* and *vulture*, the *humming-bird* and *ostrich*, the *owl* and *peacock*, the *raven* and *nightingale*, what a surprising variety is there of structure, proportion, colour, and song!

22. Hairy birds having projecting ears, a mouth furnished with teeth, and whose body is carried on four paws, armed with claws, are they birds in reality? Are quadrupeds, that fly by the assistance of great membraneous wings, really such? The *bat* and *flying-squirrel* are these strange animals, which are so proper for establishing the gradation that subsists between all the productions of nature. The ostrich, with the feet of a goat, which rather runs than flies, seems to be another link which unites birds to quadrupeds.

The class of quadrupeds is not inferior in variety to that of birds. These are two perspectives of a different taste, but which have some analogous points of view. *Carnivorous* quadrupeds answer to birds of *prey*. Quadrupeds that live on herbs, or seeds, answer to birds that feed on the same kind of aliment. The *screech-owl* among birds is the same as the *cat* among four-footed animals. The *beaver* seems answerable to the *duck*. Quadrupeds may be divided into two principal classes. The first comprehends quadrupeds with a *solid* foot; the second comprises quadrupeds whose feet are furnished with *claws*, or *toes*. Amongst quadrupeds of the first class, from the stag to the hog, and those of the second, from the *lion* to the *mouse*, what a diversity of models, sizes, and motions, do we observe!

By what degrees does nature raise herself up to man?

How will she rectify this head, that is always inclined towards the earth? How change these paws into flexible arms? What method will she make use of to transform these crooked feet into suple and skilful hands?

Or, how will she widen and extend this contracted stomach? In what manner will she place the breasts, and give them a roundness suitable to them?

The ape is this rough draught of man; this rude sketch; an imperfect representation; which, nevertheless, bears a resemblance to him, and is the last creature that serves to display the admirable progression of the works of God!

CHAP. IV.

Continuation of the gradual Progression of Beings.

1. THE relations which the plant bears to those beings that surround it, and from whence it derives its subsistence, are purely corporeal, or comprehended entirely within the sphere of the properties of bodies. The animal, which is more excellent, is allied to nature by other connections, and by such as are of a more exalted kind. Like the plant, it vegetates; like her, it receives that nourishment from without, which promotes the growth of it; and, like her, it multiplies. But, to those different actions, are superadded *feeling*, or the *perception* of what passes within him. This sense of feeling is connected with several others, which are produced various ways; and they are all accompanied either with *pleasure* or *pain*.

Agreeable sensations inform the animal of the relations which certain bodies have to its preservation or welfare: *disagreeable*, or painful sensations, advertise him of qualities which are hurtful. He is then the centre to which divers objects are directed; he draws near some, and keeps at a distance from others. The nerves, or that cluster of small fibres which extend themselves from the brain to all parts, like small cords, constitute the immediate organ of feeling.

2. Does spiritual perfection always answer to corporeal, in animals? If this be true, how comes it to pass,

that the simple *ostrich* appears inferior, in point of understanding, to the *lion pismire*, which is placed so much beneath it in respect to structure?

Let us not mistake. The marks of understanding exhibited to us, in some insects, are surprising; inasmuch, as we do not expect to meet with them in those animals we scarce think capable of feeling: our imagination is warmed, and we ascribe to those insects more genius than they really have.

On the contrary, we form high expectations from larger animals; so that we are very apt to degrade them, as soon as we perceive they fall beneath the idea we entertained of them. There are some, however, whose mind does not display itself by striking marks, but by a great number of less sensible ones; which, being united, form a degree of understanding superior to that of the most industrious insect. Such, without doubt, would appear to be the case of the *ostrich,* were she better observed: we reproach her with indifference towards her eggs. It is affirmed, that she leaves the care of hatching them to the sun. This reproach is turned into a commendation with regard to the ostriches of Senegal; since an exact observer has bestowed on them the attention they require. In these scorching climates, the sun sufficiently heats, in the day-time, an ostrich's eggs, that are hid in the sand; the warmth of the mother would be then unnecessary, or even hurtful to them: she would keep the sun from them, whose rays are more active and efficacious. But the nights in Senegal are very cool, and the eggs would be in danger of growing cold; then the mother never fails to procure them heat, by sitting upon them during that time.

At the Cape of Good-Hope, where it is not so hot as at Senegal, the ostrich sits night and day, like other birds. The young ones peck in a few hours after they are hatched; but they are not able to walk till several days afterwards: the dam takes care to place near them such food as is proper for them.

Lastly, it is to be remarked, that there is a kind of society among large animals; their memory retains faithfully a certain number of signs and sounds. Their soul is affected by a variety of perceptions: sight and hearing alone furnish an abundant source to them. Insects afford us but very imperfect images of this. The *lion pismire* is ignorant of every thing but the snare he has laid, and the prey he expects in consequence of it: his eyes, which are motionless and unmeaning, differ widely from ours; nor is he affected by any sound.

3. Those are, undoubtedly, the most perfect animals, whose sphere of understanding extends to the greatest number of objects. These are various in their operations, can shift about, and compass their ends by different ways.

The *polypus* only knows how to lengthen and contract his arms: the *spider* spreads a net with a geometrical regularity: the *falcon* and *dog* pursue their prey with sagacity: the *ape* presumes to imitate *man*.

Has God created as many species of souls as of animals? Or, is there only one species of soul in animals, differently modified; according to the diversity of organization? This question is absolutely impenetrable by us. All we can say concerning it is this: if GOD, who has always acted by the most simple means, has thought proper to vary the spiritual perfection of animals, merely by organization, his WISDOM has so ordained it.

4. At the summit of the scale of our globe is placed *man*, the master-piece of the earthly creation.

Not to dwell on the excellent construction of his body, let us consider man as an intelligent being. Man is endued with reason; he has ideas; he compares these ideas together; judges of their relations or oppositions; and acts in consequence of this judgment. He alone, of all animals, enjoys the gift of *speech*; he clothes his ideas with such signs as he thinks proper; and, by this admirable prerogative, he forms a connection between them, which renders his imagination and memory an inestimable fund of knowledge. By this means, man communicates his thoughts, and brings all his faculties to a state of perfection; by this he attains to all arts and sciences; and by means of this, all nature is subject to him.

Sometimes, with a strong and harmonious voice, he celebrates, in a poem, the virtues of a hero: at others, by a stroke of the pencil, he changes a dull canvass into a charming perspective. Here we see him, with the chissel and graver in his hand, animating the marble, and giving life to brass: there, with the plummet and square, erecting a magnificent palace. Now we behold him, by a microscope of his own invention, discovering new worlds amidst invisible atoms; or penetrating the secret exercise and motion of a particular organ: at other times, by changing this microscope into a telescope, he pierces into the heavens, and contemplates Saturn and his moons. Returning home, he prescribes laws to the celestial bodies; describes their paths; measures the earth; and weighs the sun: afterwards, he dives into the nature of beings; examines their relations, and the admirable harmony resulting from them; and, by an attentive view of their various perfections, he sees an immense chain formed, comprehending the whole.

In another station, man is occupied in such arts as contribute to the supply of his necessities or conveniencies: his reason condescends to every thing. The earth, cultivated by his care, teems every year with new productions: hemp and flax divest themselves of their bark to furnish him with clothing. The sheep abandons, for his use, his rich fleece; and the silk-worm spins, for him, her precious wool. The yielding metal is moulded in his hands: the stone softens in his fingers. The largest and strongest trees fall at his feet; and receive from him a new being. All the animals are subject to his laws; even the fiercest of them insult not his crown with impunity: he makes some serve for food; others he harnesses to his chariot; and others he condemns to till his land: many of them he appoints to be his porters, hunters, guards, and musicians. In short, man ploughs his adventurous way across the vast ocean, and, by navigation, unites the two extremities of the globe.

5. The EXCELLENCE of human reason shines likewise with a new lustre, from the establishment of *societies*. In them, virtue, honour, fear, and interest, variously employed or combined, prove the source of peace, happiness, and order. All the individuals, being mutually interwoven together, move in a regular and harmonious manner. Under the sanction of the laws, the king, prince, and magistrate, by exercising a lawful authority, promote virtue, suppress vice, and spread around them the happiest effects of their administration. In society, as in a pure and fertile climate, talents of different kinds spring up and unfold themselves. From that, the *mechanical* and *liberal* arts flourish. Lastly, society perfects friendship, that faithful companion of life, which administers consolation in our sufferings, and gives a relish to our pleasures.

6. The last mark of the greatness of man, and of his high exaltation above other animals, is the commerce he has with his CREATOR by religion.

Wrapped in the thickest darkness, the rest of the animal creation are ignorant of the HAND that formed them. They enjoy an existence, but cannot trace the AUTHOR of life. Man alone soars to GOD the PRINCIPLE, and prostrate at the foot of the throne of the ALMIGHTY, adores with the profoundest veneration, and with the most lively gratitude, the INEFFABLE GOODNESS that created him.

In consequence of those eminent faculties wherewith man is enriched, GOD condescends to reveal himself to him, and to lead him as it were by the hand in the paths of happiness. The various laws he has received from the SUPREME WISDOM, are so many lights placed at proper distances on his road, to guide him from time to eternity.

Enlightened by this CELESTIAL GUIDE, man advances in the glorious race that is set before him, and seizes the crown of life, and adorns with it his immortal brow.

7. Such is man in the highest degree of earthly perfection. But mankind have their gradations, as well as the other productions of our globe. There is a prodigious number of continued links between the most perfect man and the ape.

If you take a survey of all nations of the earth; if you consider the inhabitants of the same kingdom, province, city, or town; nay, do but examine with attention the members of the same family, and you will imagine you see as many species of men as you discern individuals.

To the Lapland dwarf, let the giant of Madagascar succeed. Let the flat-faced African, with his black complexion and woolly hair, give place to the European, whose regular features are set off by the whiteness of his complexion and beauty of his hair. To the filthiness of a Hottentot, oppose the neatness of a Dutchman. From the cruel Anthropophagite pass to the humane Frenchman. Place the stupid Huron opposite the profound Englishman. Ascend ftom the Scotch peasant to the great NEWTON. Descend from the harmony of HANDEL to the rustic songs of the shepherd. Put in the same scale the locksmith constructing a jack, and

VAUCANSON forming his automations. Reckon up the number of steps from the smith that causes the anvil to groan, to REAUMUR anatomizing fire.

Do these varieties arise from any real difference there is between human souls, independently on the organization of the body?

We shall not think so, if we pay a due attention to health and sickness, to constitution and manner of living, to climate, and education.

You may perceive what a multitude of consequences a mathematician derives from a very simple principle: place this same principle in the hands of a man of the lower class, it will remain barren, and not be productive of the smallest truth.

May not the number of just consequences which different minds deduce from the same principle, serve as a foundation for constructing a psychometer upon; and may we not presume that one time or other we shall be enabled to measure spirits as we now do bodies?

But the scale of the creation does not terminate at man. Another universe commences there, whose extent, perhaps, compared to that of this, is as the space of the solar vortex to the capacity of a nut.

There shine the CELESTIAL HIERARCHIES, like glittering STARS:

There from all parts the *angels, archangels, seraphim, cherubim, thrones, virtues, principalities, dominions, powers*, cast forth their radiant beams.

In the centre of these *august spheres*, shines gloriously the SUN OF RIGHTEOUSNESS, the EAST above, whence all the other *stars* borrow their light and splendor.

Ye planetary worlds! *celestial hierarchies!* you sink into annihilation in the presence of the LORD: your *existence* is by HIM: HE IS THAT HE IS: HE *alone* possesses the plenitude of *being*: you enjoy but the reflection of it. Your perfections are streams; the IN-

FINITELY PERFECT BEING is an ocean, an abyss, which the cherubim presume not to look into.

If we enjoy a very sensible pleasure on seeing collected, in one place, the principal productions of nature, how great must the exstasy of celestial spirits be, when they survey those worlds which God has thick sown in the vast expanse, and when they contemplate the immensity of his works!

O! the delightful employment those *superior intelligences* are exercised in, when they compare the different economies of these worlds, and weigh in the balance of reason each of these globes!

But all *celestial intelligence*, doubtless enjoy not these advantages in the same degree. There may be some perhaps to whom is granted the knowledge of one world only: others may know several; others a much greater number.

How immense must that MIND be, which beholds with a single glance the sum of all beings, and which by fathoming the *spirits* of all orbs, discerns in an instant, and without confusion, the result of all the ideas that have, do now, and will hereafter occupy them?

Ye inhabitants of the earth, who have received reason sufficient to convince you of the existence of these worlds, will you for ever be denied entrance into them? Will the INFINITELY GOOD BEING, who shews them to you at a distance, always refuse you admittance into them? No; since you are called to reside ere long among *celestial hierarchies*, you will like them fly from planet to planet: you will eternally advance from perfection to perfection, and every instant of your duration will be distinguished by the acquisition of farther degrees of knowledge. Whatever has been with-held from your terrestrial perfection, you will obtain under this economy of glory: *you will know even as you are known.*

Man is sown corruptible, he will rise incorruptible and glorious: these are the words of the *apostle* and philosopher: the covering of the seed perishes; the germ subsists, and assures man of immortality.

Man therefore is not in himself what he appears to be. What we discover of him here below is only the gross foldage under which he crawls on the earth, and which he must shortly cast off.

The *brain* is a small organical machine, destined to receive the impressions made on the different parts of the body, and to transmit them to the soul. It is by means of this that the soul acts on various points of the body, and adheres to nature.

The extremities of all the nerves, radiate to the seat of the soul: it is in some measure the centre of this admirable collection, the threads of which are so numerous, fine, delicate, and full of motion.

But the nerves are not stretched like the strings of an instrument of music. Animals that are entirely glutinous, are notwithstanding very sensible.

We then admit there is a fluid in the nerves, whose subtilty prevents our seeing it; and which serves both for the propagation of sensible impressions, and muscular motion.

The instantaneousness of this propagation, and some other phenomena, indicate that there is a certain analogy between the nervous fluid and fire or light.

We know that all bodies are impregnated by fire. It abounds in aliment. It is extracted from it by the brain, from whence it passes into the nerves.

The seat of the soul, the immediate organ of feeling and thought, can be no other than a composition of this vital fire. The brain which we see and feel, must therefore only be the case or covering of the ethereal machine, which constitutes the real seat of the soul.

It may indeed be the germ of that *spiritual* and *glorious* body, which REVELATION opposes to the *animal* and *vile*.

The *resurrection*, then, will only consist in a prodigiously rapid unfolding of this germ, which lies hid in the brain.

These senses are the foundation of those relations which the animal body bears to terrestrial bodies. The seat of the soul, or the little ethereal machine that constitutes it, has parts corresponding with the grosser senses, since it receives motions from thence, and transmits them to the soul. These parts, by the opening of the germ, will acquire a degree of perfection incompatible with the present state of man. But this germ may likewise contain within it new *senses*, which will disclose themselves at the same instant, and by multiplying in an almost infinite degree the relations of man to the universe, will aggrandize his sphere, and render it equal to that of *superior intelligences*.

An organized body, formed of elements analogous to those of light, will, we may reasonably suppose, stand in need of no repair. The *spiritual* body will preserve itself by the mere energy of its mechanism.

And if light or ether do not gravitate at all, man in a *glorified* state will be enabled to transport himself at pleasure into every point of space, and will fly from planet to planet, with the swiftness of lightning.

The senses, as they will then be brought into subjection to the soul, will no longer rule over her. Separated for ever *from flesh and blood*, there will remain in her none of those earthly affections which resulted from them. Transported into the regions of light, the human understanding will present no ideas to the will but those of the highest good. It will then have no other than lawful desires, and God will be their constant and ultimate end. It will love him from gratitude; fear him from a principle of love; and will adore him as the SUPREMLY AMIABLE BEING, and as the *eternal source* of life, perfection, and happiness.

CHAP. V.

Of the various Relations of Terrestrial Beings.

1. WE have seen, that all is relation in the universe, but we have only hitherto taken a distant view of this fruitful truth. We may now approach nearer to it, and bestow our attention on the most interesting particulars.

The union of souls to organized bodies, is the source of the most abundant and most wonderful harmony that exists in nature. A substance without extension, solidity, and form, is united to an extended, solid, and formed substance. A substance that thinks, and which has a principle of action in it, is united to a substance void of thought and purely passive. From this surprising connection there springs a reciprocal commerce between the two substances: a kind of action and re-action, which constitutes the life of *organized animated* beings. The nerves, being variously agitated by objects, communicate their motions to the brain, and to these impulses the perceptions in the soul correspond, which are totally distinct from the cause that occasions them.

The rays which proceed from an object strike my optic nerve, I have a *perception* that points out to me the presence of the object. They affect this nerve in a violent manner: I have a *sensation* which I express by the term of *pain*.

The diversity of *senses* by which the soul receives the impression of objects, produces a diversity in her perceptions and sensations. The sentiments occasioned by the motion of the nerves of sight, differ absolutely from those that are produced by that of the nerves of hearing. The sense of feeling has no likeness to that of taste. These are different *modifications* of the soul, which correspond to different qualities of the objects.

But how can the nerves, which do not seem susceptible of a greater or less degree of bulk, length, composition, or tension, or of quicker or slower vibrations, occasion in the soul such a prodigious variety of perceptions as we experience? Is there such a relation between the soul and the machine to which it is united, as for certain perceptions to correspond continually with the nerves of a determinate size, sructure, and tension? Are there nerves appropriated to different corpuscles, to the impression whereof various perceptions are attached? Are the pyramidial form of the *papillæ* of the taste and feeling, the winding cavities of the ear, the different refrangibilities of the rays of light, so many proofs of the truth of this? Be that as it may, we are sufficiently convinced that the same sensible fibre is not liable at one, and the same time to a multitude of different impressions. But this fibre is not only destined to transmit to the soul the impression of the object; it must also preserve the remembrance of it; for a thousand instances prove that the memory is connected with the brain: how then can it be imagined that the same fibre should at once retain a multitude of different *determinations?* Nay, how can two such different substances as the soul and body act reciprocally on each other? At this question let us humbly cast our eyes downwards, and acknowledge this is one of the great mysteries of the creation, which we are not permitted to be acquainted with. The various attempts that have been made by the most profound philosophers, to explain it, are so many monuments raised to convince us both of the extent and weakness of the human mind.

2. The soul, being modified by impressions more or less strong, re-acts in her turn on the nervous system, maintains the motions there, and renders them more active or durable. From thence arise the *passions,* those secret inclinations, those restless appetites, which destroy the equilibrium of the soul, and impel her to-

wards certain objects. These are admirable instruments set to work by the wise AUTHOR of our nature, which, like favourable winds, cause the animated machines to float on the ocean of sensible objects!

The re-action of the soul on the nervous system, seems also to be the principal source of divers sensations we experience, several of which come under the denomination of *instinct* or *moral sense.*

Objects do not strike immediately on the soul: she only receives impressions by interposed *mediums*; the senses are the mediums. The action of objects then is modified by them in a determinate relation to nature, or to the constitution of each medium. The aptness, either greater or less, wherewith sensible fibres yield to impressions from without, transmit them to the soul, and renew the remembrance of them there, together with the quality and abundance of the humours constitutes the temper. In animals, temper governs all: in man, reason regulates the temper; and the temper, when under due regulation, facilitates, in its turn, the exercise of reason.

The passions receive nourishment, grow, and become strong, like the fibres which are the seat of them. Learn then your temper; if it be vicious you are to correct it, not to destroy it; for you would thereby destroy the machine itself; but skilfully to divert its course, and carefully to avoid every thing that may contribute to add new strength to it, and swell the waters of such a dangerous torrent.

3. The senses are not only intended to raise in the soul perceptions of every kind, they likewise revive *memory* in her. A perception which is present to the memory does not essentially differ from that which the object excites. This produces perception by means of sensible fibres appropriated to it, and on which its action is displayed. The recollection of perception then depends on a motion which operates in these fibres, in-

dependently of the object: for whether the organ receives its motion from intestine causes, or from the object, the effect is the same with regard to the soul, and perception is instantly *present* to her.

Experience proves, that if any series of perceptions whatever affects the brain for a certain time, it thereby contracts a habit of re-producing it in the same order. It is likewise certain, that this habit appertains to the brain, and not to the soul: a burning fever, a ray of the sun, or a violent commotion may destroy it, and such causes influence only the machine.

All perceptions derive their origin from the senses, and the senses transmit to the seat of the soul the impressions they receive from objects. But objects act on the organ by impulsion only: they impress then certain motions on the sensible fibres. So that a perception, or a certain series of perceptions, are connected with one or divers motions which operate successively on different fibres.

And since the reiteration of the same motions, on the same fibres, effects in them an *habitual* disposition to produce them afresh in a constant order, we may infer from thence that the sensible fibres are so constructed as to produce in them changes or *determinations* more or less durable, which constitute the precious groundwork of the memory and imagination.

But the sensible fibres are nourished like all the other parts of the body: they assimilate or incorporate with themselves alimentary matter: they grow, and whilst they receive nourishment, they continue to perform their proper functions. So that nutrition conduces to preserve to the fibres these determinations, and causes them to take root there; for as the fibres increase, they acquire a greater degree of consistence. We may hence discover the origin of *custom,* that powerful queen of the sensible and intelligent world. The memory, by preserving and recalling to the soul the *signs* of perceptions, by assuring her of the *identity* of the perceptions recalled, and of those which have already affected her, by connecting present perceptions with the antecedent ones, forms in the brain a fund of knowledge, which increases in richness every day.

The imagination, being infinitely superior to a Michael Angelo or a Raphael, delineates in the soul a faithful image of objects; and from divers representations which it composes, forms in the brain a cabinet of pictures, every part of which moves, and is combined with an inexpressible variety and swiftness.

The brain of man, then, may be considered as so many mirrors, wherein different portions of the universe are painted in miniature: some of these mirrors exhibit but a small number of objects; while others represent almost the whole of nature. What is the relation between the mirror of the mole and that of a Newton? What images were there in the brain of a Homer, a Virgil, or a Milton? What mechanism must that have been which could execute such wonderful decorations? That mind which could have read the brain of a Homer would have there seen the Iliad represented by the various exercise of a million of fibres.

4. Of all the senses, the *sight* is that which furnishes the soul with the quickest, most extensive, and most varied perceptions: it is the fertile source of the richest treasures of imagination, and it is to that principally that the soul owes the ideas of *beauty,* and that *varied unity* which ravishes it.

But by what secret mechanism are my eyes made capable of communicating to me such lively, varied, and abundant perceptions? How do I discover, with so much ease and quickness, every object that surrounds me?

Three *humours* of different density, each lodged in a transparent capsule, divide the inside of the globe of the eye into three parts. On the bottom is spread a kind of cloth, or very fine membrane, which is only the expansion of a nerve, whose extremity terminates immediately at the brain. A black skin lines the whole inside of the globe: at the fore part of it is a round orifice, which contracts or dilates itself according as the light is more or less strong. Six muscles, which are placed on the outside of the globe, move different ways, and the rapidity of those motions is excessive.

What need is there of these humours, this cloth, this tapestry, this aperture which contracts and dilates itself? The light comes to us from the sun, in a right line; but these rays become *crooked,* when the density of the *mediums* through which they pass increases or diminishes: this is called the *refraction* of light.

To the property of *refracting* light, joins that of *reflecting* from the body it enlightens. There issue then luminous streaks from all points of the objects, which bear the image of these points.

The humours of the eye are the lens of the camera obscura: the cloth, or *retina,* are the pasteboard: the black skin which hangs within the ball performs the office of a shutter that excludes the light; it extinguishes the rays whose reflection would render the image less distinct; the *ball,* by contracting or dilating itself in proportion to the strength of the light, moderates the action of the rays on the retina: the nerve, placed behind this, communicates to the brain the various concussions it receives, to which divers perceptions correspond.

5. Such are the admirable relations which WISDOM has placed between our eyes and the light; those which it has established between light and the surfaces of different bodies, whence *colours* proceed, are not less worthy our attention.

A ray which falls on a glass prism, divides into several principal rays, each of which bear its *proper* colour. The oblong image which this refraction produces, affords several coloured stripes, distributed in a regular order: the first, reckoning from the upper part of the image, is *red,* the second *orange,* the third *yellow,* the fourth *green,* the fifth *blue,* the sixth *indigo,* the seventh *violet.* These stripes do not glare; but the eye passes from one to the other by gradations or shades.

The rays which bear the highest colours, as the red, orange, and yellow, are those that *refract* or curve the least in the prism. They are also such as *reflect* the first on inclining the instrument.

From thence it follows, that each ray has its fixt degree of *refrangibility.* Make one of these rays pass through several prisms at the same time, it will afford you no new colours; but it will constantly retain its primitive colour, which is an invincible proof of its *immutability.* Present a lens to seven rays divided by the prism, you will reunite them into a single ray, which will afford you a round image of a shining *white.* Take only five or six of these rays with the lens, you will have but a dusky white. Only reunite two rays, you will make a colour that will partake of both. A stream of light then is a cluster of seven rays, whose reunion forms *white,* and the division of which produces seven principal and *immoveable colours!*

What is now the source of that infinite diversity of colours, which embellishes every part of our abode? The particles which compose the surface of bodies, are so many little *prisms,* variously inclined, which break the light, and reflect different colours. Gold, divided into very thin plates, appears blue when opposed to broad day-light. The greater or less thickness of the plates contributes then to the diversity of colours. Whence proceeds that beautiful azure which tinges the canopy of heaven? The ground of the heavens is black: this ground viewed through the body of air which surrounds us, must appear blue to us. Whence proceeds this smiling verdure which adorns our fields? The lamellæ of the surface of plants are disposed in such a manner, that they remit only green rays, whilst they afford a free passage to others. If green pleases our sight, it is because it holds precisely a medium between the seven principal colours. But who can remain insensible of the care which NATURE has taken to depart from uniformity in this case, by multiplying in so great a degree the shades of green? You admire this magnificent rainbow, which delineates at large to you the colours of the prism: the beauty and vivacity of its shades ravish you: you suspect that nature must have been at a vast expence to compose this rich girdle: some drops of water, on which the light breaks and reflects in different angles, are the sole cause of it.

You are struck with the splendid gilding of some insects; the rich scales of fishes attract your notice; NATURE, who is always magnificent in design and frugal in execution, produces these brilliant decorations at a small charge: she only applies a brown thin skin on a whitish substance; this skin performs the office of varnish to our gilded skins, it modifies the rays which issue from the substance it covers. The glossy green of the leaves of plants is owing to the same art. They owe their lustre and shades to a fine, smooth, transparent, glossy, and whitish membrane, which clothes a substance that is always of a *rough* green, and of a stronger or fainter dye. It is this green, modified by this membrane, which constitutes the colour peculiar to leaves of every species.

It is apparently the same with regard to the enamelling of flowers, and perhaps likewise to the colouring of fruits. This is a new branch of optics, which, were it dived into as it deserves, might be attended with some interesting consequences.

The direct light of the sun, or that of the day only, tinges the leaves as it colours that of fruits. Leaves, whilst they are inclosed within the bud, are whitish or yellowish. They preserve this colour, if obliged to grow in a tube of blue paper, where the air and heat may have free access. The plant then *stars*, as the gardeners term it, sending forth an excessively long and slender stalk, and the leaves unfold themselves but very imperfectly. The light is in a continual and very rapid motion; it acts perpetually on the surface of bodies, which it penetrates more or less. By its small reiterated strokes on leaves, it modifies the surface of them by little and little, and insensibly disposes it to reflect the green colour.

Colours then in objects are only a certain disposition of parts totally distinct from the perceptions which they cause in the soul. It is the same with respect to all our perceptions and sensations. The senses, by representing to us bodies under different appearances, shew us the various qualities; and to these qualities different ideas in the soul correspond. We conclude from hence, that the same objects do not affect all sensible beings in an equal manner. It is even doubtful whether two individuals of the same species have precisely the same perceptions in presence of the same object.

Were we to contemplate the world by the organs of all those sensible beings which inhabit it, we should perhaps see as many worlds as we should employ glasses. What difference would there appear in the mulberry-tree, examined through the organs of a silk-worm, from our conception of it! What diversity between the *stamina* viewed through the eyes of bees, and those which the botanist observes! How extensive would be the knowledge of that being who could be acquainted with all these different impressions!

6. *Fire,* which is dispersed through all nature, offers to us an infinity of properties; let us confine ourselves to give an account of the most interesting. Fire, being subtle, elastic, and continually agitated, penetrates all bodies; it warms, dilates, burns, melts, calcines, vitrifies, volatilizes, and dissipates them, according to the nature of their composition or principles. This subtle element becomes visible only by borrowing a body: it secretly unites itself to an inflammable and unknown substance, and provided with this body, unites itself to other bodies, and enters into their composition. It is by means of the same union that it becomes sensible in *electrical* experiments, sometimes in the form of luminous tufts, sometimes in that of

crowns, flashes, sparks, and that it fulminates, bursts, strikes, pierces, burns, inflames.

By a gentle agitation, fire enlivens all organized bodies, and conducts them by degrees to their perfect growth. It foments the branch in the bud, the plant in the grain, the embryo in the egg: it gives suitable preparations to our food; it subdues metals to our use, over the formation of which it precides. By that we are enabled to give matter all those forms which our necessities or conveniences require. To that we are indebted, in a particular manner, for that transparent matter, which being stretched out into thin leaves, or fashioned like tubes, vases, globes, lenses, furnishes us with various instruments, and enriches us with new eyes, which help us to discover the smallest objects, and bring nigh to us the most remote.

From the action of fire on earth, sulphur, oils, and salts, the various species of fermentations and mixtures result, which are the objects of the researches of the chymist, and the soul of the three kingdoms. Being concentered by lenses or mirrors of every kind, it acquires a strength greatly superior to that of the hottest of our actual fires, and in an instant reduces green wood to ashes, calcines stones, melts and vitrifies metals.

Being excited, collected, condensed, modified, extracted, directed, and applied by electrical machines, it becomes the fruitful source of a thousand phenomena, which art diversifies every day. Sometimes, when extracted from a globe of glass, it runs with an inconceivable rapidity along an iron wire, and causes light bodies, placed at a league distance from the globe, to feel the impression of it. Applied by the same means to paralytic limbs, it restores life and motion to them.

Being present in all parts of the atmosphere, it collects itself in stormy clouds, from whence it is again extracted by art; and a *Le Monnier,* equal to the fabulous Jupiter, holds the thunderbolt, and disposes of it at his pleasure. It is likewise fire that communicates to air and water, when reduced into vapours, that prodigious force which renders them capable of shaking the earth, and breaking the hardest bodies.

Lastly, it is fire, that by penetrating fluids, preserves to them their fluidity. As it is exact itself, in putting itself in equilibria, it passes from those bodies where it is most abundant to those where it is least so, and carrying with it the most volatile particles, it deposits them on the surface of the latter, where they appear in the form of vapours, exhalations or mists.

7. The air, by its fluidity, thinness, weight, and spring, is next to fire, the most powerful agent in nature. It is one of the great principles of the vegetation of plants, and of the circulation of liquors in all organized bodies. It is the receptacle of the particles which exhale from different matters: and had we eyes sufficiently piercing, we should see it in the abridgement of all the bodies that exist on the surface of our globe. From vapours and exhalations which it carries in its bosom, and disperses into all parts, are produced *aqueous* and *fiery* meteors, which are so useful, but sometimes dreadful.

The air does not only receive bodies: it even enters into their composition. When divested of its elasticity, it unites itself to the particles which compose them, and augments their bulk. But being more unalterable than gold, it resumes its former nature when these bodies change or are dissolved. Being disturbed in its equilibrium, it swells the sails of our ships, and conveys to our countries those rich fleets that cause plenty. Becoming impetuous, it causes tempests and hurricanes: but even this impetuosity is not without its use: the air, by this means, divest itself of noxious vapours, and the waters being strongly agitated, are preserved from a fatal corruption.

Lastly, the air is the vehicle of sounds and odours, and under these new relations it is essentially allied to two of our senses. The partial vibration which commotion excites in a *sonorous* body, communicates itself to all the globules of air that immediately encompass this body. These globules cause the like vibrations in those contigious to them: and this continues in the same manner to greater distances than we are able to determine. A fine and elastic membrane spread at the bottom of the ear like the parchment of a drum, receives these concussions, and conveys them to three small bones, placed end to end, that communicate them, in their turn, to certain bony and winding cavities, lined on their inside with nervous filaments, which join to the brain by a common trunk. The greater or less degree of swiftness of these vibrations produces seven principal tones, analogous to the primitive colours. From the combined relation of various tones, harmony proceeds.

The infinitely small particles that are continually detached from the surface of odoriferous bodies, float in the air, which transports them every where, and applies them to the nervous membranes that are distributed in the inside of the nose. The concussions which these corpuscles occasion therein, pass afterwards to the brain by the lengthening of the nervous filaments.

8. All climates have their productions, all parts of the earth their inhabitants: from the frozen regions of the bear to the burning sands of the torrid zone, all is animated: from the top of the mountains to the bottom of the vallies, every thing vegetates and respires. The waters and the air are peopled with an infinite number of inhabitants. Plants and animals are themselves little worlds that nourish a multitude of people, as different from each other in their figure and inclinations as the great people are which are scattered over the surface of our globe. What am I saying? The smallest atom, the least drop of liquor are inhabited. Wonderful harmony! which, by thus suiting different productions to different places, leaves none absolutely desert!

9. A reciprocal commerce connects all terrestrial beings. Inorganized beings answer to organized as to

their centre: the latter are designed for each other. Plants are allied to plants; animals to animals. nimals and plants are linked together by their mutual services. Behold how closely this young ivy entwines itself round this majestic oak! It draws its substance from it, and its life depends on that of his benefactor. Ye great ones of the earth, ye represent this oak: refuse not your support to the indigent; suffer them to approach you, and to obtain from you sufficient to relieve their necessities.

Consider this caterpillar thick-set with hair; the birds dare not touch it: notwithstanding which, it serves them for food: by what means? a fly pierces the living caterpillar; she lays her eggs in his body: the caterpillar remains alive; the eggs hatch; the young ones grow at the expence of the caterpillar, and are afterwards changed into flies which serve for sustenance to the birds.

There are continual wars betwixt animals; but things are so wisely combined, that the destruction of some of them occasions the preservation of others, and the fecundity of the species is always proportionable to the dangers that threaten individuals.

10. All is metamorphosis in the physical world: forms are continually changing: the quantity of matter alone is invariable: the same substance passes successively into the three kingdoms: the same composition becomes by turns a mineral, plant, insect, reptile, fish, bird, quadruped, man.

The organized machines are the principal agents of these transformations: they change or dissolve all matters that enter within them, and that are exposed to the action of their secret springs: they convert some into their own substance, others they evacuate under divers forms, which render these matters proper for entering into the composition of different bodies. Thus, animals that multiply prodigiously, as some species of insects, have, perhaps, for their principal end that of metamorphosing a considerable quantity of matter for the use of different compounds. By that means, the vilest matters give birth to the richest productions; and from the bosom of putrefaction there issues the finest flower or the most exquisite fruit!

The AUTHOR of NATURE has left nothing useless. What is consumed of the dust of the stamina in the generation of plants, is very trifling if compared with the quantity each flower furnishes. WISDOM itself then has created the industrious bee, that makes use of the superfluous part of this dust with such art and economy as could not be too much admired in the most skilful geometricians.

The earth enriches us every day with new gifts, whereby she would at length be exhausted, if what she supplies us with were not restored to her. By a law, which we do not pay a proper attention to, all organized bodies become uncompounded and insensibly change in the earth. Whilst they suffer this kind of dissolution, their volatile parts pass into the air, which transports them every where: so that animals are buried in the atmosphere as well as in the earth and water; we may even doubt whether that portion which the air receives be not the most considerable in bulk. All these particles dispersed here and there, soon enter into new organical wholes, destined to the same revolutions as the former: and this circulation, which has subsisted from the beginning of the world, will continue as long as it endures.

CHAP. VI.

Of Vegetable Economy.

1. THERE is no source of physical relations that is more abundant than the economy of organized bodies. let us cast an eye on what it offers to us on the most interesting nature. Our plan does not lead us to dive into a subject that exhausts the sagacity of a philosopher.

Organical ECONOMY, taken in the most extensive sense, is that system of laws according to which the vital functions operate in organized bodies.

Considered in a less view, organical economy presents us with two classes of objects: the first comprehends the *structure, arrangement,* and *exercise* of the different parts of organized bodies: the second comprises the various effects that result from organization.

2. The plant *vegetates*, is nourished, grows, and multiplies. The saline, unctuous, and subtle slime, which the water separates from the coarse earth, and keeps in a dissolved state, is the principal nutriment of plants. The different species of manure only contribute to the fertilizing of land, in proportion, as they introduce into it a great quantity of a spongy powder or active salt. If a natural philosopher succeeds in raising plants, and causing them to bear flowers and fruits in other matters than earth, for instance, in the powder of rotten wood, deal, saw-dust, very fine sand, moss, cotton, paper, sponges; the reason is, because several of these matters

either change insensibly in the ground, or actually contain earthy parts; or the water which moistens them is itself charged with these particles, which the organs extract, prepare, and assimilate.

After having been admitted into the body of the root by the extremity of the *fibres*, the nutritious juice rises into the *ligneous* fibres, from the trunk or stalk, and passes into the *utricles* that adhere to them: it is there prepared and digested. It afterwards enters into the *proper vessels*, under the form of a coloured fluid, more or less thick, which we may conjecture to be with respect to the plant, what the chyle or blood is to the animal. Being filtered by finer, or more winding pipes, it is at last conveyed to all the parts, whereto it unites itself, and increases their bulk.

The extreme fineness of the canals for the *sap*, which renders them, in some measure, *capillary* pipes; the action of the air on the elastic sheaths of the air-vents, and the impression of these last on the ligneous fibres they contain, or by which they are comprised; the heat that rarefies the sap; and, above all, that which, by acting on the surface of the leaves, draws thither the superfluous nutritious juice, and occasions the evaporation of it, seem to be the principal causes of the ascent of this fluid in plants. The quantity of nutriment which a plant derives from the earth, is in proportion to the number and size of its leaves; the smaller or fewer in number the leaves are, the less it draws. The nutrition of vegetables is likewise effected immediately by their leaves. They do not only serve for raising the sap, preparing it, and discharging its superfluity; they are, moreover, a kind of roots that pump from the air the juices they transmit to the neighbouring parts.

The dew, which rises from the ground, is the principal foundation of this aerial nourishment. The leaves present it to their inferior surface, which is always furnished with an infinite number of small pipes that are always ready to observe it; and that the leaves may receive no prejudice in the exercise of this function, they are disposed with such art on the stalk and branches, that those that immediately precede do not cover such as succeed them. Sometimes they are placed *alternately* on two opposite and parallel lines; sometimes they are distributed by pairs, that cross each other at right angles; sometimes they are ranged on the angles of *polygons*, circumscribed on the branches, and so disposed that the angles of the inferior polygon correspond with the sides of the superior: at other times, they ascend the whole length of the stalk and branches, on one or more parallel *spiral* lines.

Ye sceptics, can you inform me why plants are disposed with so much art? You will, perhaps, deny that plants imbibe the dew by their inferior surface! But what would you say, were one to inform you, that among leaves, exactly resembling each other, and taken from the same tree, such as have been steeped by their inferior surfaces in vessels of water, have continued green for the space of whole weeks, and even months; whilst those that have been placed, by way of experiment, with their upper surface in the water, perished in a few days?

Herbs that are always immersed in the thickest beds of dew, and that grow much faster than trees, have their leaves formed in such a manner, that they pump in the moisture nearly alike by both surfaces, sometimes more copiously by the upper ones.

Observe lastly, that the inferior surface of the leaves of trees is commonly less smooth and glossy, and of a paler colour, than the opposite surface. This remarkable difference between the two sides of the leaf, sufficiently indicates that they have different uses.

3. By a mechanism which is very simple, the root forces itself into the earth; the branches shoot out on each side; the leaves expose their superior surface to the open air; and their inferior surface to the earth, or the inner part of the plant. Sow a seed the contrary way, you will observe the radicle and little stalk to bend

backwards; the former in order to reach the earth, and the latter to gain the air. Keep a young stalk inclined, its extremity will grow upwards. Bend the branches of all sorts of plants; cause the inferior surface of their leaves to turn towards the sky; you will soon perceive that all these leaves will turn back again, and resume their former position: which motion will be executed with a quickness proportionate to the heat of the sun, or supleness of the leaves. Sow different kinds of seeds in a closet or cellar; carry thither some small twigs, having their extremity steeped in vessels full of water; the leaves of the young plants, and those of the twigs, will incline their upper surface to the windows or air-holes.

Consider the leaves of divers species of herbaceous plants; of the *mallow* for instance: you will remark that they follow the course of the sun. In the morning you will see them present their upper surface to the east; towards the middle of the day this surface will face the south; in the evening it will be turned to the west. At night, or in rainy weather, these leaves will be horizontal, their inferior surface looking towards the earth.

Trace, likewise, the leaves of the *acacia*; as soon as they are heated by the sun, you will observe all their foliages draw together by their upper surface: they will then form a kind of gutter, turned towards the sun. In the night, or in moist weather, you will see the foliage turned the contrary way, and contracting themselves by their inferior surface: they will then form a gutter that will face the earth.

4. Do not seek for *circulation* in plants: as they are more simple than animals, every thing in them is performed with less apparatus.

In the day-time, the action of the heat on the leaves, draws to them in abundance the nutritious juice. The small excretory vessels that appear in the forms of globules, pyramids, filaments, separate the more aqueous, or gross parts of the juice, that rises from the root. The air contained in the trachæ of the stalk and branches, by dilating itself more and more, presses the ligneous fibres, and by that means accelerates the course of the sap, at the same time that it causes it to penetrate into the neighbouring parts.

When night approaches, the inferior surface of the leaves begins to perform one of its principal functions: the little mouths it is provided with open themselves, and receive the vapours that float in the atmosphere. The air of the trachæ is confined within them; their diameter is lessened; the ligneous fibres being less pressed, enlarge themselves, and admit the juices conveyed to them from the leaves: these juices join themselves to the residue of that which had arisen in the day-time, and the whole mass tends towards the roots.

This seems to be exactly the mechanism to which the motion of the sap may be reduced. You now see, more clearly, the design of the direction of the leaves, and of their admirable reverting; the inferior surface being intended for imbibing the dew, should face the earth, from whence this vapour rises gradually at sunset. But when I say that the principal office of this surface, at least in trees and shrubs, is to receive the dew, I would not infer that the opposite surface is incapable of it; that may, perhaps, absorb vapours that are more rare.

Experiments that are well made, seem to prove that the inferior surface of the leaves of trees serve likewise for insensible perspiration. Those leaves, in which this surface was endued with a matter impenetrable by water, drew in and transpired much less, in an equal time, and with the same management, than leaves of the same size and likeness, whose inferior surface had not been endued with such a varnish. It seems to have resulted from the same experiments, that there is but little perspiration by the upper surface; we may thence infer, that one of its principal functions is, to serve for a helter or defence to the lower surface: and that, no doubt, is the use of the glossy varnish observable on the superior surface; all which agrees with the almost spontaneous motions and directions of the leaves, and with their symmetrical distribution round the stalks and branches.

5. The plant being inclosed in miniature within the fruit or seed, is there encompassed with a quantity of flour, which, after being diluted by the water that has penetrated the inclosures, ferments, and furnishes the *germ* with its first nourishment. Being moistened by the delicate milk, in proportion to its weakness, it grows from day to day: in a short time its coverings become incommodious; it endeavours to divest itself of them, and pushes forth a little root, which proceeds to seek for more nourishing juices in the earth. The little stalk appears in its turn: as it is destined to live in the air, it pierces the earth, and darts perpendicularly into the aerial fluid. Sometimes it carries along with it the remains of the teguments that had enwrapped it in the germ state; at other times, it is accompanied by two leaves, which are very different from those of a mature age: these are the *seminal* leaves, whose principal use is, probably, to refine the sap.

Though it is divested of its swaddling-clothes, if we may so term them, the young plant is not at full liberty: it is not in a condition to be exposed so early to the impressions of the air and sun. All the parts remain, for a short time, folded together, nearly as they were in the seed; but the root, by extending and ramifying itself more and more, conveys to the vessels a considerable quantity of sap, which soon opens all the organs.

At its first appearance the plant is almost gelatinous: it assumes, by little and little, a greater degree of consistence by the incorporation of the juices which flow to it from all parts. That part of the stalk next the root increases in bulk, extends itself, and hardens first of all: as the hardening augments, the extension diminishes: at length, it entirely ceases in this part, and continues in that which immediately follows. Such is the nature of the progression observed in the whole plant.

Wood, whose hardness is sometimes equal to that of stone, is formed of a succession of concentric layers, that are detached every year from the inside of the rind, and harden as they advance in age.

6. Vegetables multiply by *seeds, shoots,* and *slips.* The *pistil* and *stamina* are, to plants, what the organs of generation are to animals; the former incloses the seed; the fine powder of the latter fecundates it. Both sexes are frequently united in the same subject; and those species are real hermaphrodites: others bear the pistil on one branch, and the stamina on another. A third sort are like the greater part of animals, distinct males and females: the former are furnished with a pistil, and the latter with a stamina. This is all we know with regard to the generation of plants.

When the stamina are cut off, the seed remains unfruitful. The same thing happens when any one that has pistils, has not, in its neighbourhood, another provided with stamina: the pistil is always so disposed as to be able to receive the dust of the stamina. Its top is perforated with holes, proportioned to the diameter of the grains of this dust, and its inside is divided into several canals, whose diameter diminishes the nearer they approach to the bottom: at the base of the pistil the seed is deposited. Every grain of the dust of the stamina is a box, wherein floats, in a kind of very thin vapour, an infinite multitude of other very minute grains: this box opens itself to the moisture, and discharges a small mist of globules or grains.

The shrinking of the trunks indicates that the *containing* globules do not reach to the bottom of the pistil; but the *contained* globules, or grains, are set at liberty by the action of the moisture which the trunk imbibes, which, by opening the little box that incloses them, permits them, by this means, to penetrate to the *ovary.*

7. Vegetables multiply by *shoots.* They push forth from the circumference of their root several succours, which become plants themselves, and propagate their species in like manner: the branches and young shoots may likewise be considered as ingrafted on the principal plant, making one body with it. The germs, which are dispersed within the plant, infold themselves there without any sensible fecundation, and reach to the surface of the bark; they appear there in the form of a small oblong and rounded body, composed of several parts, ranged in a very regular manner, and shaped like tubes, shells, &c. This little body is the *bud,* which, like the seed, incloses the young plant under several coverings, all the parts of which are completed with abundance of art.

The little stalk shoots forth a similar bud at its upper extremity: this bud opens, and produces a second stalk, grafted on the first, which it lengthens. This new stalk produces a third; the third a fourth, and so on successively. When the tree has attained its full growth, it is composed of a series of small trees, placed end to end. It is the same with respect to branches and boughs, all having one and the same life, and forming only one organical whole.

Bulbous plants, instead of young shoots, send forth suckers. The bulb, which is formed of several membranes, or coats, placed on each other, contains, in like manner as the seed and bud, a plant in miniature. The sucker is a small bulb that shoots out on the sides of the principal one, and which is designed to succeed or replace it: sometimes this replacing is performed with such quickness and circumstances as are very surprising. Whilst the principal bulb is wasting, the sucker thickens and spreads itself, and in a short time becomes the principal bulb.

We may compare this bulb to a species of earth, that exhausts itself in order to furnish suitable juices to the young plant: it may also be looked upon as a *placenta,* that filtres and prepares the nutritious juice. The leaves of some herbaceous plants form spherical masses, that are pretty compact, and seem to perform the office of a bulb. The head of a cabbage spends and wastes itself, in order to contribute to the unfolding of the minute stalk it contains. Place one of these heads on a vessel full of water, and it will exhibit to you the same phenomena as the bulb of a flower.

8. The branches that bend down from certain trees to the earth, take root there, and become themselves young trees. Human industry carries this kind of multiplication to a much greater extent. By means thereof, a single branch or root, divided into several parts, becomes so many individual plants. What do I say? It can even cause a tree to be produced from the smallest shred of a leaf. Such is the multiplication from *slips*.

The organs essential to life being dispersed throughout the whole body of the subject, the slip that is detached from it, and planted in the earth, is of itself capable of forming new productions; it has every thing necessary for the unfolding of the radicles and buds. Thus a single leaf takes root, and vegetates by its own strength.

There is another kind of multiplication that is very remarkable, which consists in planting one or more slips, not in the earth, but in the trunk or branches of a living tree. This is *grafting*; the first idea of which may perhaps have been owing to the accidental union of two branches or two fruits.

The next cause of the union of the graft with its subject, is in the intercourse of the sap-vessels with each other; and this intercourse depends ultimately on the relation of their parts, and particularly on that of their consistence, and the liquors contained in them. By the assistance of a graft the gardener causes the wild stock to produce the finest fruits; he gives youth to trees, and gathers plums from the almond tree, and pears from the ash. Filtrating, and the preparation of the juices of the subject by the vessels of the graft, occasion these productions. The *roll* which is always formed at the *insertion*, and is composed by the interweaving of a prodigious number of fibres, is one of the principal instruments of these preparations. The more or less perfect analogy of the juices proper to the *subject* with those that are peculiar to the *graft*, favours in a greater or less degree the unfolding of the latter. The nearer or more distant relation between the time in which the sap in the subject continues, and that in which the graft has been accustomed so to do, contributes likewise more or less to the success of the operation.

9. The body of the plant is in a continual state of motion. It always tends to produce, either the bark, a bud, or a root. Make an incision in a tree: the wound will cicatrise. A greenish roll will in a short time be seen at the top of the wound, afterwards on the sides, and at length towards the bottom. This roll is a new rind, which is about to cover the wood again, without uniting to it. Observe what passes with respect to this; you will perceive in it certain distinct and glutinous nipples, and small reddish spots dispersed here and there, which you will find to be a growing bark. A matter that is partly transparent, whitish, and mucilaginous, will seem to raise up this bark. All these glutinous substances will thicken, increase in length, and become stronger, and in a little time what was at first of a gluey nature will be herbaceous, cortical, and ligneous. The cicatrice will at length entirely close itself, and restore the communication between all the vessels.

The *wood* does not only differ from the *bark* by its density, but it has likewise organs that are not to be met with in the latter. It seems to be peculiarly possessed of air-vessels. When a new rind seems to convert itself into wood, this conversion is only in appearance. Nature does not create more air-vessels than are suited to one entire plant. But a multitude of fibres, that are destined to become wood, pre-exist under the new rind, and unfold themselves with it and by it, as we see the butterfly unfold itself in and by the caterpillar. Whilst wood is nothing more than a mucilaginous drop, it is not on that account the less wood, than when, being transformed into a pillar, it is made to support the enormous weight of an edifice.

In the union of the *graft* with its *subject,* we likewise perceive a glutinous substance to spring from each of them, which spreads, ramifies, and is formed into a ball in both, becoming by degrees herbaceous, cortical, ligneous, and composes above the *insertion* a roll which entirely covers it. So that the whole body of the plant is furnished with small fibres on the inside, which only wait for favourable circumstances to display themselves. These circumstances are a wound, an incision, or a simple ligature. These fibres are the elements of cortical or ligneous beds, which by spreading themselves on all sides, furnish the necessary repairs. The wound, incision, and ligature, occasioning the nutricious juices to flow towards these invisible fibres, expand them, and render them perceptible to us.

What these fibres perform in the regeneration of the bark or wood, the *germs* effect in the reproduction of a branch or young shoot. The fibres of the bark or wood do not unite themselves into bunches, in order to compose a *bud* or branch in miniature. This branch is already completely formed in its germ: it there possesses the elements of all the beds, whether cortical or ligneous, which it will hereafter exhibit under different proportions.

CHAP. VII.

Of Animal Economy.

1. THE *nerves,* which extend themselves into all parts from the brain, are distinguished into several principal *divisions,* that are more or less numerous, or more or less extended. Each division reaches to the part for which it is destined, and whose structure corresponds with the functions appointed for it to exercise.

Feeling, sight, hearing, taste, and smell, are five kinds of senses, which contain under them an almost infinite number of species. The shaking which the mediate or immediate impression of objects produces on the nerves, give birth to those different kinds of sensations, which may all be reduced to *feeling,* of which they are properly only modifications. The organs of the senses are the instruments of these modifications. The number, extent, and delicacy of the *senses,* constitute the degree of *animal perfection.*

The nerves, which seem to resemble the strings of a musical instrument, are not stretched like them. Some animals are endued with an exquisite sensation, that are themselves little otherwise than a thick jelly? How then can we admit of elastic strings in this jelly? While the fetus is altogether gelatinous, it regulates at that time its members. With what amazing swiftness then must the impressions of objects communicate themselves to the soul! and with what wonderful celerity must the members obey the will! Thus we are led to suppose in the nerves a very subtle and elastic fluid, whose motions, being analogous to those of light or electrical fluid, produce all the phenomena of sight. The *animal spirits* are this fluid, which the brain extracts and prepares, and continually conveys into the nerves, and by the nerves into all parts, which it nourishes, moves, and animates.

2. An animal had in vain received senses, by means of which it can distinguish between what is useful or hurtful, if it were not able to give itself any motion for the attaining the one, and avoiding the other. It is therefore furnished with organs that procure to it this faculty. These organs are the *muscles,* which by the dilatation and contraction, and by the lengthening and shortening of the fibres that compose them, communicate to all parts the motions, which are suited to the wants of the animal.

It is evident from experiments, that the nerves contribute to the exercise of the muscles. The spirits which they disperse therein, insinuate themselves into all the vesicles, dilate them, and by that means put the organ into action.

One property of the muscular fibre (whose effects are diversified a thousand ways, the cause of which is concealed from us) is that, by virtue whereof it contracts itself on the touch of any body either solid or liquid. This is called *irratability.* By means of this, different parts of the animal continue to move, after they have been separated from the entire body; and the heart when detached from the breast, performs a number of pulsations, which cease as soon as the blood in the cavity is evacuated.

3. From that part which gives admittance to the food to that from whence issue the remains of the grosser aliment, there is one continued canal, which is formed, differently in different parts of its extent. There are three principal parts distinguished in it, the *œsophagus,* the *stomach,* and the *intestines.* All these are formed of various membranes laid on each other, and which are themselves composed of fibres differently interwoven. The muscles, wherewith one or several of these

membranes are furnished, impress divers motions on the organ, the principal of which, called the *peristaltic* motion, bruises the aliment, and forces it from place to place.

The *œsophagus* receives the grosser nourishment, and transmits it to the *stomach*, that prepares it: it afterwards passes into the *intestines*, where it undergoes new preparations. From thence it enters into some very small vessels, that convey it to those of *circulation*, where it assumes the name of *blood*.

Whilst the most delicate part of the aliment is subject to all these preparations, the grosser part is evacuated by different ways. Sometimes the animal discharges it as a *sediment*; sometimes, being transformed into a subtle liquor, it is carried to the surface of the skin by an infinite number of very fine vessels, whose exterior apertures are sometimes so small, that a grain of sand is capable of covering several thousands of them.

Other vessels, which, like them, communicate with the surface of the skin, pump in the vapours that float in the air, and convey them into the blood.

4. *Circulation* is that perpetual motion by which the blood is conveyed from a point internally to the extremities, and flows back again from the extremities to the same point. The point from whence the blood springs, is called the heart. It has two motions, one of contraction, or *systole*, by means of which it forces out the blood contained in its cavity; the other of dilatation, or *diastole*, by which it receives the blood again.

Two kinds of vessels join to the heart: the *arteries*, which convey the blood to the extremities: and the *veins*, which carry it back from the extremities to the heart.

The arteries, have, like the heart, their systole and diastole, and divide and subdivide themselves, as do the veins, into an infinite number of branches, which diminish in diameter in proportion to their distance from their origin. The perpetual motion of circulation prevents the corruption and extravasation of the nutritious fluid, rectifies it more and more, and disposes it insensibly to renew the nature of the animal.

5. *Respiration* comprehends two alternate motions; one of *inspiration*, which gives admittance to the air within; the other, of *expiration*, which expels it, filled with the vapours of the animal.

The *lungs* are the principal instrument of respiration. They are principally formed of a collection of cartilaginous and elastic vessels, which after being divided and subdivided into a prodigious number of branches, meet in different parts, and terminate at one or more common trunks, called *trachæ*, or air-vessels, whose aperture is on the outside of the body. The ramifications of the air-vessels are connected with the vessels of circulation, and accompany them in their passage through the lungs.

6. The blood is that rich fund from whence nature derives that diversity of materials she employs with so much art in the construction of her wonderful edifice. This, as it goes from the heart, meets, here and there on its passage, with certain organical, and as it were knotted masses, in which it is deprived of part of its principles.

We cannot yet penetrate the true mechanism of *secretions*: we can only faintly perceive, that they may operate by a gradual diminution of the vessels which proportions them to the smallness of the particles that are to be separated. They may likewise bear some affinity to the configuration of these particles, and favour the extraction of them by means of the slackening which their folds and various circumvolutions occasion to the circulation. Thus it is, that by causing the aliment to pass through an infinite number of strainers, nature is enabled to *assimilate* it to the animal, and incorporate it into his flesh. This is then neither chyle nor blood; it is a much more refined liquor, and known by the vague name of lymph.

We cannot sufficiently admire the prodigious apparatus of vessels which perform the secretions of different kinds. The kidneys, the liver, the pancreas, &c. are labyrinths in which the most consummate anatomist is bewildered. We can only discover an inconceivable mass of white tubes, of an extreme minuteness, folded together in thousands of different ways, which do not admit of any injection, through adhering to the blood-vessels, and being placed end to end by imagination, would have formed a chain of several leagues in length. This is all that art has discovered in the secretory organs. But what a number of interesting particulars do these minute, hollow cylinders contain, which have escaped our notice and instruments! What varieties should we not discover in their structure, functions, and exercise, were we permitted to descend to the bottom of this abyss, which conceals from us one of the greatest mysteries of nature! All the animal liquors are more or less mixed, and these small tubes no doubt sufficiently diversify themselves to separate the various molecules that must necessarily enter into the composition of every liquor. What then must be the structure and fineness of those that filtre this so subtle fluid, compared to ether or light, whose operations are diversified almost to infinity!

7. If we knew how a single fibre *grows,* we could tell how the animal *grows*; for his whole body is only an assemblage of fibres differently formed and combined. Growth always operates by nutrition. This incorporates into the fibre molecules of an heterogeneous nature, which extend in every part. The fibre incorporates into itself the heterogeneous molecules, according to its own nature. A fibre is not itself composed of other fibres: these of still other fibres: of which there would be no end. But the fibres is formed of molecules or *elements,* whose nature, proportions, and arrangement, respectively determine the *species* of the fibre, and adapt it to such or such a function. Thus the elements of the fibre ultimately effect assimilation, which, by uniting with the nutritious molecules, that have an *affinity* with them, give them at the same time an arrangement like that

which they have in the fibre. The extension of the fibre supposes that its elements may separate more or less from each other; but this separation hath its bound, and these bounds are those of the growth. In proportion as the fibre grows, it acquires more solidity; for the number of incorporated molecules increase every day, since it only grows by the successive incorporation of molecules of a foreign nature. The more the solidity augments, the more the suppleness diminishes. There are more molecules, more coherence, and more attraction under the same foldage. The fibre then tends to a state of hardness, and the last term of its hardening is the last term of its growth. When therefore the fibre has acquired its full growth, it is a little organized whole, composed of its *elementary* molecules, and of all such as nutrition has incorporated with them during the time of their growth. If then we could separate from the fibre all those molecules which it has assimulated, we should restore it to its *primitive* state. This may be applied to all organized bodies. They are, if we chuse to term them so, net work. A secret force impels the aliment into the meshes. It increases them in bulk, and supplies them by little and little. It likewise insinuates itself into the elements of the solid mass itself. The net-work stretches, thickens, and at length becomes hard.

8. We may easily comprehend, that all the parts of an animal have such strict and indissoluble connexions between them, that they must necessarily have always co-existed together. The arteries imply veins; both of these imply nerves; the latter the brain; this the heart; and all of them suppose a multitude of other organs.

In the germ of a chick there is at first perceived a *vital point*, whose constant motion attracts the attention of the observer. The alternate and quick contractions and dilatation of the living point, sufficiently indicate that it is the heart. But this heart seems to be without any covering, and to be placed on the outside of the body. Instead of appearing in the form of a minute pyramidical mass, it bears the resemblance of a semicircle. The other viscera appear successively, and range themselves after each other, round the living speck. We cannot as yet discover any general folding; all is transparent or nearly so; and we only perceive by little and little those teguments which are appointed to cover all the parts.

In its first beginnings the animal is almost entirely fluid. It assumes by degrees the consistence of a jelly. All the parts have at that time situations, forms, and proportions, that differ greatly from those they will afterwards acquire. Their minuteness, softness, and transparency, serve to strengthen the illusion. We persuade ourselves that a bowel is naked, because the transparency of its coverings prevents our seeing them.

Would you have a short and easy demonstration of this? When the lungs of the chick are first perceivable, their size is but the thousandth part of an inch. It would have been visible at the fourth part of these dimensions, were it not endued with the most perfect transparency. The liver is much greater at its first appearance; its transparency alone renders it invisible. It is the same with respect to the kidnies; whilst they do not even appear to exist, they separate the urine. The heart forces the blood into the arteries sooner than we could imagine, and it can only be perceived by the growth of the embryo, which is never more accelerated than at the very beginning.

Many other facts concur with these to establish the pre-existence of *organical wholes*. We are now sensible that many insects multiply, like plants, by *slips*. We cut them into pieces, and each piece regenerates, and becomes a perfect animal. Earth worms are ranked in the number of those insects that are reproduced from their disjoined parts; and being very large, the phenomena of their regeneration is very perceptible. The piece that is cut off never acquires any growth; it always remains as the section left it; only it falls away in a greater or lesser degree. But after some time there appears a very small whitish pimple at its extremity, which increases by degrees in bulk and length. There are soon discovered rings, which are at first very small and very close. They spread themselves insensibly every way. New lungs, a new heart, a new stomach, disclose themselves, and with them a number of other organs. This piece, which is newly produced, is extremely slender, and altogether disproportioned to the part on which it grew. We may imagine that we see a worm growing, that is grafted at the end of this stump, endeavouring to lengthen it. This little vermiform appendage unfolds itself slowly. At length it equals in thickness the piece from which it was cut, and exceeds it in length. It can no longer be distinguished from it but by its colour, which is somewhat fainter.

Here then is a new organical whole, which grows from an ancient one, and constitutes the same body; there is an *animal* slip that grows, and expands itself on the stump of an animal, as a vegetable slip does on the trunk of a tree. Remark that the flesh of the piece cut off does not in the least contribute to the formation of the part regenerated; the stump only nourishes the bud; it being the soil in which the latter vegetates. The part then that is reproduced passes through all the degrees of growth, by which the entire animal itself had before passed. It is a real animal, which pre-existed in a very minute form in the great animal that served it for a matrix.

Vegetable productions exhibit to us the same consequences. If a tree be topped, that does not lengthen the trunk of it: but it sends forth a multitude of buds, in each of which a little tree is comprized; for the bud or branch that springs from it is a tree that is grafted on the trunk that nourishes it.

Every seed in like manner comprizes a plant in minature. On every slight inspection, we may very easily discover the stalk, leaves, and root of this little plant; but the curious rise much higher, and distinguish, in a bulbous root or growing bud, those flowers that do not blow till the ensuing year.

When the evolution commences in an organized whole, its form differs so prodigiously from that which it will afterwards assume, that we should be apt to mistake it, were it not to accompany it in all its progress. Observe how the parts of a plant are folded together, entwined, and concentred in the seed or bud. Is this that majestic tree which will ere long overshadow a large space of ground? This the flower that will so gracefully display itself? This the fruit that will assume such a regular figure? You can now only perceive an unformed mass of knotted filaments: yet this little chaos may already contain in it a world, where all is organized and symmetrical.

You have seen frogs in their first state; they appear at that time to consist only of a large head and a long tail: such is the chick when it begins to expand itself. A very slender tail, stretched in a strait line, is joined to a large head; and the tail contains all the rudiments of the composition; nay, is the very composition itself; and the transparent fluid in which it floats, constitutes the whole of those soft parts with which it is afterwards covered.

The same revolutions, therefore, which occasion the heart of the chick to be transformed from its semicircular shape of that of a pyramid, bring the chick itself to a state of perfection. If we were permitted to penetrate to the foundation of the mechanism whereby these successive changes are effected, what a degree of certainty would our knowledge of animal economy acquire? We should contemplate in an egg, the mysteries of the two kingdoms. And how greatly would our admiration of that ADORABLE WISDOM be increased, which, by the simplest means, ever attains the most noble ends?

9. Thus, the more we ascend to the origin of organized beings, the more we are persuaded of their having pre-existed before their first appearance; not such as they first appear to us, but disguised; and where it possible for us to trace them still higher, we should undoubtedly find them still more disguised, and should be at a loss to conceive how they could

afterwards acquire that form under which they present themselves to our view.

We can then form no idea of the *primitive state* of organized beings: that state which I conceive to be given them by the hand of HIM who has ordained all things from the beginning.

The forms of vegetables and animals, which are so elegantly varied, are in the system of this admirable pre-ordination, only the last results of that multitude of successive revolutions they have been liable to, and which perhaps commenced at their first creation. How great would be our astonishment, could we penetrate into these depths and pry into the abyss! We should there discover a world very different from our's, whose strange decorations would infinitely embarrass us. The state in which we conceive all organized bodies to have been at first is the *germ* state; and the germ contains, in minature, all the parts of the future animal or vegetable; it does not then acquire organs which it had not before; but those organs which did not hitherto appear, begin now to be visible. We do not know the utmost limits of the division of matter, but we see that it has been divided in a prodigious degree: from the elephant to the mite, from the globe of the sun to a globule of light, what an inconceivable multitude of intermediate degrees are there! This animalcule enjoys the light, it penetrates into its eye, it there traces the image of objects: how extremely minute must this image be! and how much more minute must that of a globule of light be, when several thousands, and perhaps millions, enter at the same time into this eye! But great and small are nothing in themselves, and have no reality but in our imagination. It is possible that all the germs of the same kind were originally joined or linked into each other, and that they are only unfolded from generation to generation, according to that progression which geometry endeavours to assign them.

10. A *barren* egg has a *yolk* as well as a fruitful egg;

and a ray of light has lately sprung which has greatly brightened the shades in which the mystery of generation is yet involved.

Bestow your whole attention on this, you will then discover an important truth. A membrane clothes the inside of the yolk of an egg; and this membrane, which is only a continuation of that which clothes the *slender* intestine of the chick, is common to the stomach, pharynx, mouth, skin, and epidermis. Another membrane enfolds the yolk externally, and this membrane is only a continuation of that which covers the intestine, it unites with the mesentery and peritoneum. The arteries and veins that gently move in the egg, derive their origin from the mesenteric arteries and veins of the embryo. The blood which circulates in the yolk receives the principle of its motion from the heart.

The yolk then is essentially a dependance of the intestines of the embryo, and together with that composes one and the same organized whole; so that at its primary period, it is in some measure an animal with two bodies: the head, trunk, and extremities compose one of these bodies; the intestines and yolk the other. At the end of the incubation the second body connects with the first, and both together form only one.

But since the yolk exists in eggs that have not been fecundated, it necessarily follows that the germ existed before fecundation. This consequence is self-evident: you have lately seen that the yolk is an essential part of the chick; you have observed the strict communication between them. The chick then has never existed without it. The membranes and vessels of the former are only a continuation of the membranes and vessels of the latter. And what a number of other things are there which are common to both, and which prove that they have never existed separately! The chick was then entire in the egg before fecundation. It does not, therefore, owe its origin to the liquor furnished by the cock, but was stretched in minature in the egg previous to it. Consequently, the germ belongs solely to the female.

Such is the grand conclusion which immediately flows from facts.

11. The yolk has its liquors, which are conveyed to it by the arteries belonging to it: they circulate, and without veins there is no circulation. But the arteries and veins of the yolk take their origin from the mesenteric arteries and veins of the fetus: the heart of this latter, therefore, is the principle of that circulation which is performed in the yolk. At the time of fecundation the fetus does not weigh the hundredth part of a grain: the yolk, at that time, weighs a dram; it has vessels proportioned to its size. Now if the germ existed entire before fecundation, that which we stile generation is not the same thing with it, but is only the beginning of an *evolution*, which will, by degrees, bring to open day such parts as were before hid in impenetrable darkness.

But the germ cannot be unfolded in an egg which has not been fecundated, and incubation would only accellerate its eruption. What does it then want to enable it to continue to grow? It has all the organs necessary for evolution. It has even already attained to a certain degree of growth, for eggs grow in young pullets; their ovaries contain them of all sizes: the germ grows there likewise. Why cannot it enfold itself more than it does? What secret force retains it within the limits of invisibility?

Growth depends on the impulsion of the heart: a greater degree of growth depends on a greater impulsion. This degree of impulsion, consequently, is wanting in the heart of the germ that has not been fecundated.

This demonstrates a certain resistance in the parts of the germ: as it grows this resistance augments in proportion. Some resist more than others; the bony parts, or such as will hereafter become so, more than the membranous, or those that always must remain so.

The heart of the germ then hath need of a determinate strength to surmount this resistance: its strength is in its *irritability*, or in the power it has of contracting itself on the touch of some liquid. Wherefore to augment the irritability of the heart, is to augment its impulsive force.

Fecundation, without doubt, increases this force, and that can alone increase it, since it is only by the intervention of it that the germ passes over the narrow limits that it retained in its first state.

12. The fecundating liquor then is a true *stimulus*, which being conveyed to the heart of the germ, excites it in a powerful manner, and communicates to it a new activity. Herein consists what we may call *conception*. Motion being once impressed on the little moving body, is there preserved solely by the energy of its admirable mechanism.

But it is not sufficient that the heart should acquire a force sufficient to surmount the resistance of *solids*; it is likewise necessary that the fluid which it conveys to them, and which should *nourish* them, be proportionable to the exceeding fineness of the vessels. Such a blood as ours would not circulate in them. The blood of the embryo is at first a whitish liquor, it grows yellow by degrees, and afterwards red. The more the impulsion of the heart dilates the vessels, the more gross, heterogeneous, and colouring particles they admit.

The prolific liquor then is not a mere *stimulus* but is likewise a nutricious fluid, appropriated to the extreme delicacy of the germ: it has already discharged the functions of a nutritious fluid in the fecundating individual; it has caused its comb, spurs, &c. to grow and give strength to all his parts.

Being conveyed by the arteries to all the parts, it unites itself to the nature of each. From thence proceeds *growth*, which we do not pay a sufficient attention to.

It is not long before the chick loses the first form. Wings, thighs, legs, and feet, spring out from its long tail: every thing is formed and disposed on a new model. The little animal, which before was stretched out in a strait line, becomes more and more curved. It is successively clothed with muscles, tendons, flesh, and feathers, and in eighteen or twenty days is a perfect chick.

13. If the chick pre-existed in the hen, it is probable the horse pre-existed in the mare. This would be more than probable, if it could be demonstrated that the young of viviparous animals are enclosed in *eggs*, and that all the difference between viviparous and *oviparous* may be reduced to this, that the former are hatched in the belly of their mother, and the latter after their issuing from it.

On the two sides of *viviparous* females there is a body resembling a bunch of grapes, whose berries are bladders full of a limpid liquor: these are the *ovaries*; they communicate with the *matrix* by two canals, which they call *tubes.* The prolific liquor penetrates into the matrix, and passes through the tubes into the ovaries. Thus fecundation is performed. Fetus's have more than once been found in the ovaries itself. Nay more, there has been found in a vesicle of the ovary a complete fetus sketched in miniature.

The vesicles of the ovary are real *eggs,* which, after fecundation, descend through the tubes into the matrix, and are there in some measure brooded on. In a short time they send forth small roots, which convey the nourishment to the embryo. The suppleness of their membranes admits of their extending and making way for the growth of the little animal. It is true, the *growing* of eggs is not familiar to us; but the history of insects furnishes us with many examples of it. It even exhibits to us insects that are at one time viviparous, and another oviparous. The young were in that case at first lodged in eggs; sometimes the mother lays her eggs, and at another brings forth living young ones, which were hatched from these eggs whilst they were yet in the matrix.

It is therefore the same with respect to the vesicles of the ovary, as the eggs of the hen, a germ pre-exists in them, but its transparency conceals it from us, fecundation renders it visible.

14. But if an ass cover a mare, there will be produced from this commerce an animal that will not properly be a horse, but a *mule.* Nevertheless, a horse was delineated in miniature in the egg of a mare: how then was it transformed into a *mule?* Whence did it acquire these long ears and slender tail, so different from those of the horse? Dissection increases the difficulty: that informs us that this kind of transformation does not only affect the exterior part of the animal, but the interior likewise. The voice of the mule is very like that of the ass, and does not at all resemble the neighing of a horse. The organ of the ass's voice is an instrument that is very much compounded. A drum, of a singular structure, lodged within the larynx, is the principal part of this instrument: this drum does not exist in the horse, but is found in the mule.

The liquor furnished by the male consequently penetrates the germ, since it there produces such great changes: but these relations of the prolific liquor to the male that furnishes it, must necessarily depend on the organs that prepare it.

There are then in these organs vessels that separate the molecules relative to different parts of the great whole: these molecules are carried to the corresponding parts of the germ, since these parts are modified by the action of the prolific liquor. Therefore, it incorporates itself with the germ, and is the first aliment of it, as I said above.

The organs of generation in the ass have then a relation to his ears and larynx; for they prepare a liquor which modifies the ears and larynx of the little horse enclosed in the egg. The prolific liquor creates nothing, but it may change what already exists: it does not engender the chick, which existed before fecundation.

Growth depends on nutrition, the latter on incorporation: at the same time that a part grows it acquires solidity. An excess of growth in a part, then, supposes a super-abundance of nutricious juices, or such as are more active. The excessive growth which the ears of the horse acquire by the influence of the liquor of the ass, indicates that this liquor contains more molecules, appropriated to the unfolding of the ears, than that of the horse, or that the molecules of the first are more active than those of the second.

The extreme softness, I should rather say fluidity, of the germ, renders every part of it extremely modifiable. Those changes which you cannot conceive in an adult, depend here on the slightest causes.

But if the fecundating liquor modifies the germ, this latter, in its turn, modifies the action of that liquor. By virtue of its organization it tends to preserve its primitive state, resists more or less every new arrangement, and never gives way without always retaining something of its primitive form.

15. Every organical production, which has more or less parts than the species requires, or constructed otherwise, is a *monster*. The *mule*, which doth not engender, is therefore a *monster*.

The object of enquiry in a celebrated dispute was, whether certain monsters were such *originally* or *by accident?*

It is evident, that the *mule* is not a monster *from its origin*. Monsters do not exhibit so much constancy and uniformity. Does an egg of which the mule is formed offer itself in the ovary of the mare just at the instant in which the ass fecundates it?

Two branches, fruits or leaves, graft themselves accidentally, and afterwards compose but one and the same whole. Art performs other more extraordinary engraftings, in all of which there is nothing originally monstrous.

That which happens between two fruits that ingraft themselves, or are ingrafted by force, may happen in the matrix between two eggs, or in an egg between two germs. Two fetus's that are united only by the spine, perfectly resemble two fruits that are grafted *by contact*. An egg sometimes contains two yolks, consequently it then contains two germs. How easy a matter is it for them to engraft themselves together as they unfold! We have seen a chicken with four feet, which undoubtedly proceeded from a like union. The germs, which are first fluid, and for a considerable time gelatinous, are very penetrable. If they come in contact they will mix together in part. Similar organs, which at least half penetrate each other, will subsist in the other moiety. We see clearly this reciprocal penetration in a human fetus having two heads on a single body. This monster was evidently formed of two moieties of the fetus connected together.

If their gelatinous state renders germs very penetrable, it favours with much greater reason their union by grafting, or that of some parts to each other, either of the same germ, or two or more germs. The *graft* is united to its *subject* only by gelatinous, or at least by herbaceous fibres: such fibres are proper for forming new productions, and for connecting and intermingling together. Two polypus's unite together much more easily than two rinds: they are abundantly softer.

16. *Accidental* grafts may give birth to monsters, which we should term inexplicable, by this principle; but you have not forgot that all organical parts have forms and situations in the germ which differ prodigiously from those they will have in the unfolded fetus. Recall to mind the *chick* in its first form, its heart in that of a simi-circle, and you will comprehend that those conjunctions, which appear impossible to you in the fetus, may be easily effected in the germ.

The *analogy* of parts likewise favors their union: this analogy results from that of the elements. Two membranes are more disposed to unite than a membrane and a bone, and similar parts of the same organ than parts of different organs.

Lastly, evolution is not uniform in all parts of the germ, they grow unequally, and this inequality of growth may influence the effects of contact, pressure, adhesion, &c. Thus, a monster that is produced with superfluous members, may derive them from a germ that has perished, and of which only these members remained. We plainly see how many causes may destroy such, or such a part, and produce a monster *by defect.*

But all monsters, *by excess,* might not owe their origin to the union of two germs. Certain parts may grow excessively by the concurrence of particular circumstances, and augment the number of similar parts in the same individual. A subject with twenty-six ribs is really a monster by excess. It has been proved that supernumerary ribs are entirely owing to the unnatural developement of a bony appendage of the transverse apothysis of one of the vertebræ. The causes which operate in the like unfoldings, act nearly as the liquor of the ass on the ears and larynx of the horse.

As supernumerary ribs unfold themselves, so two or three ribs unite themselves into a single one, and these kind of cases are not rare, either in the vegetable or animal kingdom. Such parts as almost touch each other, are very apt to unite: two drops of jelly, and of the same jelly, unite very easily.

17. The principles I have laid down concerning the generation of animals, are likewise applicable to that of plants. What the prolific liquor is to the former, the *dust of the stamina* is to the latter. There is a wonderful analogy betwixt these two classes of organized bodies. The seed, which so nearly resembles the egg, does therefore, in all probability, contain a germ, which existed in an invisible manner before fecundation, which makes it sensible to us. It appears first of all like a greenish or yellowish speck. It has been thought that a grain of the stamina dust has been perceived in this speck: the germs have on this account been placed in this dust, and introduced themselves into the seeds, which were destined to receive and nourish them. But

can we discover the germ in the egg before fecundation? Notwithstanding which, it pre-exists there: it is highly probable that it likewise pre-exists in the seed, and that its minuteness, together with the transparency of its parts, conceals it from our sight. Will a philosopher argue, that because a thing is invisible to us, it does not therefore exist?

18. An exact observer has taken a good method to clear up the mystery of the generation of plants; he considered what has resulted from the *fecundation* of divers species by the dust of different species: he has seen *mules* that have been well described proceed from it: these mules, when combined with other species, have produced new ones; the resemblances have always been in a direct proportion to the *dust*; the changes and alterations have always been sensible; the female has had some superiority. The privilege of *fecundity* has adhered more exactly to what came from her than to that which proceeded from the male. Do not these curious observations themselves indicate, that in vegetables, as well as in animals, the germ originally belongs to the female.

CHAP. VIII.

Of animal Economy, considered in Insects.

1. THE sketch I have lately drawn of animal economy, affords a slight idea of what constitutes the essence of life in most animals. We shall now treat of the principal varieties which the organization of different species presents us with. Insects, hitherto little known, exhibit some singularities in this very respect, to which we shall confine ourselves by way of preference, in order to avoid such details as might carry us to too great a length.

We have already seen, in some measure, the different parts contained in the composition of these little machines: we will now contemplate their exercise and various effects.

2. The mechanism of *respiration* is very obscure in insects: we only know, that in them it differs greatly from that in those animals which are most known to us. But we judge with greater certainty concerning this difference by the comparison of the organs, than by that of their exercise. When a drop of greasy liquor is applied to one, or several stigmata of an insect, the corresponding parts become paralytic: the interception of the air in one part is followed by that of liquors, or spirits. When we stop up all the stigmata, the insect dies immediately: if we afterwards open them, we shall perceive the inside to revive. The air which then pene-

trates the open orifices of the trachæ, evidently produces this kind of resurrection.

The trachæ, or air-vessels, are divided and sub-divided in a prodigious degree. May they not resemble so many sieves, which, by separations suitably contrived, are capable of furnishing to each part an air of a more or less subtle nature, as occasion requires? There are commonly reckoned to be nine stigmata on each side of the body; but sometimes they are more in number, at others, fewer. The same insect has some that are of greater or less importance to it, or whose functions are more or less necessary. In several species, the principal stigmata are placed behind; in others, at the head: instead of stigmata, they are pretty frequently observed to have little tubes of different lengths.

3. The *circulation* of the blood is performed in insects with great regularity. We trace it by our sight: in some species of long and transparent worms, we may see the heart, or principal artery, contract and dilate itself successively in every part of its extent. It seems to be composed of a great number of little hearts, placed end to end, that transmit the blood to each other.

We are yet ignorant in what manner the blood is conveyed into the grand artery: its principal ramifications, and the canals analogous to veins, are equally unknown. We are only certain, that in many species, for the most part of the creeping sort, the principle of circulation is towards the hinder part; whereas, in others, it is towards the head. It is very probable, that the grand artery shoots forth from both sides of it, several branches that are invisible, by reason of their extreme fineness or transparency, and that distribute the blood to every part: other branches are, without doubt, connected with them, and conduct the residue of the blood to the principal trunk of veins, which is imagined to be perceived on the opposite side of the heart. The blood of insects is a subtle liquor, transparent, commonly without colour; and though it be not in the least *inflammable*, resists, in some species, a degree of cold superior to that of our severest winters.

4. The *organs of generation*, in most insects, are placed at the extremity of the belly: that which characterizes the *male*, consists principally of one or two species of *fleshy horns*, which are turned different ways, and are generally drawn within the body, but emitted from thence at the pleasure of the insect. The hind part of divers males is also furnished with *hooks*, by means of which they fasten on that of the females: in the interior part are lodged different vessels, which are connected with the principal organ of generation, and separate the *fecundating* liquor from the mass of blood: at the end of the aperture formed in the *female*, there is joined a kind of canal, which, in many insects, sends forth several branches, called *tubes* or *ovaries*. These are species of very fine intestines, in which the eggs are ranged in a row, almost like the beads of a chaplet.

The eggs nearest the aperture are the largest, or in a more *advanced state*. They gradually diminish according to their distance: at length they become altogether invisible.

In the common passage, where the ovaries terminate, there is inserted, in some species, a very short canal, which communicates with an oblong cavity, that is considered as analogous to the *matrix*: in this cavity the liquor of the male is deposited.

Amongst *viviparous* animals the economy of the tubes changes. Sometimes the young are ranged in bunches; at others, they form a kind of cord, twisted spirally, whose length, width, and thickness, exactly correspond in number to the length and thickness of the young that compose it. The young of some viviparous insects, before they are brought forth, tear the membrane or ovary that incloses them; they are, to use the expression, on this account subject to a two-fold birth.

The eggs of insects are of two kinds: some are *mem-*

braneous, like those of tortoises and reptiles; others are *crustaceous*, as are those of birds. But whereas, in large animals, the species comprised under these genera differ only from each other by a slender variety; amongst insects these varieties are so great, that one animal does not differ more from another, than one of their eggs does from another; some of them are round, elliptical, lenticular, cylindrical, pyramidical, flat: some are quite smooth, others grooved or channelled. In short, what is more extraordinary, there are some eggs that grow after they are laid: we easily judge that they are entirely membraneous. The suppleness of their membranes admits of their extension; they have pores that imbibe the juices of the plant where they are deposited: these are minute *placentiæ* that transmit the nourishment to the embryo.

5. The distinction of insects into *viviparous* and *oviparous* does not only take place in species of different classes, but likewise in species of the same germs: there are some two-winged flies that are *viviparous*, and others that are *oviparous*.

Add to this, that some species are viviparous at one time, and oviparous at another: the *vine-fretter* furnishes an example of this.

All great animals that are known to us, are distinguished into *males* and *females*, and propagate the species by copulation. The same order prevails amongst insects, but all the species are not subject to it; and, of those that are, several afford us some very remarkable singularities. In divers species, the male is *winged*, and the female not: the *glow-worm*, which is sentenced to crawl during its whole life-time, is fecundated by an insect having four wings.

Sometimes, this striking singularity is joined with others that are still more surprising: every where else we observe a certain proportion betwixt the male and female; here this proportion vanishes entirely: the female is a colossus, on which the male walks as on a spacious spot. The ardour and agility of the male are excessive; he is almost in continual motion: the female, on the contrary, moves but seldom, and that heavily: she sometimes spends the greatest part of her life in the most perfect inactivity. In fine, the male is an insect *properly so called*; his whole body is intersected by *incisions* that are very conspicuous: the female is a spherical mass, fixed to a branch, that one would be apt to take for an excrescence or gall-nut of this branch. You will imagine that I am speaking of *gall-insects*, whose name so well explains their deceitful appearances; they are found in great numbers on the branches of many trees and shrubs; they are greatly diversified; but always affect the form of *gall-nuts*, more or less round: they imbibe the juice of the tree by the assistance of a little pump, which they keep fixed to the bark. They lay some thousands of eggs, which are piled up under the mother's belly, as they issue from it: when the whole number is laid, the gall-insect dies, and its carcase remains fastened to the branch: this is only a cod full of eggs, which one might still take for a living gall-insect, so small an appearance of life is there in this strange animal. The young are hatched in a short time, when there immediately appears a multitude of very small animated membranes, either oval or circular, which are borne on six legs, and disperse themselves on all sides with a wonderful celerity.

6. Several of the species that live in society, present us with three sorts of individuals; to wit, *males*, *females*, and *neuters*, or individuals that remain always deprived of sex: this we observe in the republics of *bees*, *wasps*, and *ants*. We know that each swarm of bees has but one female, which bears the name of *queen*; the males, which are called *drones*, pretty often amount to four or five hundred; the neuters, which are much more numerous, are sometimes forty or fifty thousand in number. These are the *ilotes* of the little Sparta; they are charged with all the labour. The queen and drone are wholly taken up in furnishing the state with citizens; she is, in

a literal sense, the mother of all her people; she lays in one year upwards of fifty thousand eggs: she produces three sorts of them, from whence are hatched three kinds of individuals of different shape. The neuters then construct three sorts of cells, to receive the eggs, and lodge the young to be hatched from them.

Divers species of insects are real *hermaphrodites*; in each individual both sexes are united, but he cannot fecundate himself; and generation depends in this case, as elsewhere, on the concurrence of two individuals.

7. Other insects are *hermaphrodites* of a more singular nature; each individual propagates without any commerce with another. We have the first example of this in the *vine-fretter*, that deserves some attention.

You have very frequently seen little flies fastened in a great number to the extremities and leaves of plants, and twisting them round in various forms: these are vine-fretters, whose species are almost as numerous as those of vegetables, and whose remarkable properties are multiplied in proportion to the attention we pay them.

They bring forth living young ones: their births are easy to trace, there needs only good eyes and a little patience. Take up a little one as soon as it is produced, inclose it immediately in the most perfect solitude, and in order to be the better assured, carry your precautions to a degree of scrupulousness; be, with respect to it, a more vigilant Argus than the fabulous one. When the little recluse has acquired a certain growth, it will begin to have young; and, after some days, you will find it in the midst of a numerous family.

Make the same experiment on one of the individuals of this family that you have tried on its chief; the new hermit will multiply like its father, and this second generation, brought up in solitude, will not prove less fruitful than the first.

Repeat the experiment from one generation to another; abate nothing of your cares, your precautions, and suspicions; proceed, if your patience will permit you, to the ninth generation, and they will all present you with fecund virgins.

After these experiments, so decisive and reiterated, you are easily persuaded that there is no distinction of sex in vine-fretters. What, indeed, would be the use of such a difference amongst a people, where all the individuals are constantly sufficient for themselves? Natural history is the best logic, because it best teaches us to suspend our judgment. Vine-fretters are really distinguished by sexes; there are males and females amongst them, and their amours are the least equivocal of any in the world. I do not know whether there are in nature any males more amorous than they.

What then is the use of coupling between insects that multiply without its assistance? Of what service can an actual distinction of sex be to real *androgynes?* The clearing up of this point depends on another great singularity. During she summer season they are *viviparous*; they all bring forth living young: towards the middle of autumn they become *oviparous*; they all then lay real eggs, which are hatched at the return of the spring. The males begin to appear exactly at the time the females begin to lay; there is, therefore, a secret relation betwixt the appearance of the males, and the laying of the females. There are always found in the bodies of the females, eggs and young, ready to be produced: the young then were originally inclosed in eggs. During the fine season, they are hatched in the belly of their mother, and are brought into the world alive: plants, at that time, furnish them with a proper nourishment, which they fail not instantly to imbibe, by the help of a very slender trunk. At the approach of cold weather, the young cannot unfold themselves in the dam's belly, in order to their being produced alive; they remain shut up in their eggs, where they are preserved the whole winter: were they to be hatched at the beginning of that season, they would soon perish for want of food: the developement depends ultimately on nutrition. Vine-fretters that are produced alive, are more unfolded in the matrix than those which are brought forth inclosed in eggs: the former then have received a nourishment in the matrix, which the others were not able to obtain there. This nourishment was sufficient to effectuate the entire opening of the germs. Had not coupling then, for its primary end, the supplying the defect of this nourishment in such germs as were not to be hatched till after they had issued from the belly of their mother?

I have treated of some species of insects, the males of which are winged, and the females not; this singularity is also to be met with amongst vine-fretters: but they offer still more to us with respect to this: some of the males are winged, and others remain their whole life-time without wings. There are likewise winged females, and other females that are not. But this is not all: the males, and particularly those that are destitute of wings, are so small in comparison of the females, that they are seen to walk upon them as a mite upon fruit: to so great a degree has nature thought fit to abound, with regard to these insects, in singularities of different kinds.

8. Animals that multiply by *slips* and *shoots*, and that may be grafted, appear to be real *zoophytes*, or *plant-animals.*

Of these some have *feet*, or members, others not. We will first treat of the latter sort.

The slime which covers the bottom of ponds and marshes, may almost be deemed a respectable thing: there the GREAT BEING has not disdained to assemble the traces of his power and wisdom. He has connected the existence of this vile matter with that of different species of worms that are destined to live in and feed upon it; and that will, one time or other, present us with the interesting sight of a new re-production, which we shall never think we can sufficiently admire, and shall therefore wonder at it in proportion as our understanding is enlightened.

All these worms are long and slender. They are not unlike the *treble* string of a violin: their body is formed of the succession of a great number of little rings, which decrease gradually as they approach the extremities. They are very soft: their head, which terminates in a blunt point, is susceptible of various motions; it contracts, dilates, lengthens, and shortens itself, at the pleasure of the insect. The mouth is furnished with a muscle that directs the functions of it, and whose exercise is pretty perceivable: the anus, which is placed at the opposite extremity, is a little oblong aperture, bordered with an analogous muscle. The whole skin is so transparent, as to admit of its being inspected within, and we may congratulate ourselves on this circumstance, since it affords us a great spectacle. The polypus exhibits nothing that has the appearance of the viscera: all its substance seems to be composed of a mass of small similar seeds. Our *fiddle-strings* are minute beings, quite differently organized; and the apparatus of the viscera, which the microscope discovers to us, seems to advance them far above the polypus. A long vessel that goes winding from the head to the tail, is what chiefly strikes the eye of the observer: by its regular alternate motions, he will soon know it to be the heart, or grand artery. The liquor that circulates in these winding passages is limpid: it is perceived, from the pulsations it excites in every part of the artery, comprized betwixt two of the rings. One would be apt to imagine each of these portions to be a real heart, and that every artery was a chain of little hearts, placed end to end, and that forced the blood from one part to another: it is seen to run with an uniform motion through all these little hearts, and rises in this manner, as by so many bladders from the tail to the head, near which it finally disappears. In different parts of the artery are discovered delicate ramifications of vessels, which may be taken for veins, there being perceived no pulsation in them: beneath, and along the artery, there is a canal, whose diameter varies at different points of its extent. It is the intestinal duct which comprehends the œsophagus, stomach, and intestines. The aliment is there seen to digest before the eyes of the observer; he follows it in its passage; sees it descend from the mouth towards the anus, and pass through every part of the canal between these two extremities. But can machines, so compounded as these, be taken to pieces without injuring their economy thereby?

That suffers not in any respect on that account. Strictly speaking, it affects these insects no more than being divided in the midst of the body; each half not only continues to live and move, but that which had no head presently forms another, and we may clearly perceive a new tail spring forth in that part which was destitute of one. In less than three days the two moieties become two complete worms.

It is more extraordinary for fourths, eighths, and sixteenth parts of our worms, to assume a head and tail: this is so speedily effected, that in a few days, all these fragments are so many perfect insects, and after a few weeks, attain to the same length as the entire worm. New rings and new viscera unfold themselves: the parts re-produced differ in no respect from the ancient ones. Thus the machine is formed anew by its own strength; and the section, which might be a means of destroying them, serves only to make them conspicuous.

I have not yet sufficiently treated of this particular. The six and twentieth part of worms, to wit, perfect atoms, are able to *re-integrate* themselves extremely well; and in the space of some months, are found to be worms of several inches in length. In these living atoms, as well as in the most considerable fragments, the circulation seems to be performed with the same regularity as in the whole worm: each atom has its little heart, and we may clearly perceive that this little heart is no other than a very small portion of the grand artery of the worm, whereof the atom was before a part.

We may weary ourselves in cutting the head off the same individual; we shall have the same task to repeat continually, because there always shoots forth a new one: we may even cause several to issue at the same time, each of which shall have their proper functions.

There is another species of these worms, amongst which the property of becoming again entire is confined in very remarkable bounds. It forms a head or tail in the middle; but if it be cut into three or four parts, the *intermediate* ones push forth a tail where a head should have been produced: this supernumerary tail, which is in no respect deficient, cannot perform the office of a head, and the unhappy insect is condemned to perish with hunger.

9. Look into this rivulet, whose bottom is covered with broken pieces of plants: What do you perceive upon them? spots of mouldiness. Do not mistake; this mouldiness is not what it appears to be; and you already begin to suspect so: you think that you greatly ennoble them by advancing them to the rank of vegetables; you conjecture they are plants in miniature, that have their flowers and seeds, and plume yourself on being able to judge of these mouldinesses in a different manner from the vulgar. Take a magnifying glass: what do you discover? some very pretty nosegays, all the flowers of which are *in bells.* Each bell is supported by a small stalk, which is implanted in a common one; you now no longer doubt of the truth of your conjecture, and cannot be persuaded to quit this microscopic parterre: you have not, however, sufficiently observed it. Look stedfastly on the aperture of one of these bells; you will there perceive a very rapid motion, which you cannot be weary of contemplating, and which you compare to that of a mill: this motion excites little currents in the water, that convey towards the bell a multitude of corpuscles, which it swallows up. You begin to doubt whether these bells are real flowers; and the motions of the stalks, which appear to be spontaneous, increase your suspicions. Continue your observations: nature herself will teach you what you ought to think of this singular production, and will fur-

nish you with fresh motives for admiring the fecundity of her ways. That is a bell which detaches itself from the cluster, and that floats along in order to fix itself to some support: follow it. A short pedicle issues from its extremity; and the bell fastens itself by the end of this pedicle: it lengthens, and becomes a little stalk. It is no longer a nosegay you are beholding; it is a single flower. Redouble your attention; you are just arrived at the most interesting moment of inspection: the flower is closed, has lost its form of a bell, and assumed that of a bud. You, perhaps, suspect that this bud is some fruit, or a seed that has succeeded to the flower: for you are loth to give up your first conjecture. Do not lose sight of this bud: it is now divided, by degrees, according to its length, and the stalk is at present supplied with two buds, less than the first. Examine what passes in both of them: they widen themselves insensibly, and you perceive a motion at the edge of the opening, which increases in swiftness in proportion as the bud unfolds itself. The mill appears again, and the two buds have assumed the form of a bell. Can a fruit, which changes into flowers, be a real fruit? Can such flowers be real flowers? that swallow little insects? Suspend your observations, and repeat them a few hours hence: your flowers are closed up as the first was; you easily guess that they will separate themselves as before, afterwards open, and present you with four bells. That is already effected, and you have a little nosegay, composed of four flowers: if you continue your inspection, you will see them augment in bulk by new divisions into two's, and soon after you will count sixteen, thirty-two, sixty-four flowers. Such is the origin of this microscopical parterre, which at first drew your attention: how much more admirable does it now appear than you then conceived it to be! What a group of wonders does a single spot of mouldiness afford! What unforeseen, varied, and interesting scenes, are transacted on a scrap of rotten wood! What a theatre does it exhibit to a thinking being! But our abode is so recluse, that we have but a glimmering view of it; how great would our ravishment be, if, the whole spectacle disclosing itself at once to us, we should be enabled to penetrate into the interior structure of this wonderful assemblage of living atoms! Our blunted eyes discover only the most striking parts of them; they only apprehend the gross parts of the decorations, whilst the machines that execute them remain concealed in impenetrable darkness! Who shall enlighten this profound obscurity? Who shall dive into this abyss, where reason itself is lost? Who draw from thence the treasures of wisdom and knowledge concealed within it? Let us learn to be content with the small portion communicated to us, and contemplate with gratitude those first traces of human understanding imparted to us, towards a world placed at such a great distance from us.

10. You cannot quit this spring, from whence you have derived so many truths, that are so astonishing: you discover in it other microscopical animals, whose form resembles that of a funnel. These are likewise polypuses. They do not compose a cluster; but cleave to some body by their inferior extremity; you are curious to know their method of multiplying. In order to this, place your microscope on one of these funnels. Of a single funnel, there are formed two by a natural division; but very different from that of bell-polypuses; so far has nature thought fit to vary her proceedings with respect to these animals. Examine what passes in the middle of the funnel. A transverse and oblique stripe indicates to you the part where the polypus is about to divide itself. The division then is made slopingly. The stripe points out the edges of the new funnel, and these are only the lips of the fresh polypus. You discover in them a pretty slow motion, which helps you to discern them. They approach each other insensibly, the body collects itself by degrees; a little swelling forms itself on the side, which is a new head. You already clearly distinguish two polypuses placed above each other. The upper polypus has the former head and a new tail; the inferior one a new head and the

former tail. The upper polypus is connected with the other only by its lower extremity. By a motion it gives itself, it is at last detached from the other; and floats away in order to fix elsewhere. The inferior polypus remains fastened to the place where the funnel was before the division.

11. Net-polypuses likewise derive their name from the exterior form of their bodies; they pretty nearly resemble that of a fishing-net. They assemble in groups, and fasten on all the bodies they meet with in fresh water. They are very transparent. In the inside of the polypus there is formed an oblong and whitish body. as soon as it is formed, it descends by degrees, shews itself on the outside, and remains fixed perpendicularly on the polypus. It produces new ones every day; and the group they compose on the exterior part of the polypus, increases in growth. If these minute bodies be eggs, they are of a singular species; they are absolutely without any covering, and are neither membraneous or crustaceous. We cannot affirm of these eggs, that young are hatched from them, but are under a necessity of acknowledging, that these little *oviform* bodies unfold themselves. This developement is accomplished in a few minutes, and the polypus becomes the same as its mother: imagine to yourself a bird that should issue from its mother's belly, entirely naked, rolled together like a ball, whose members should afterwards display themselves, and you will have a representation of the production of net-polypuses.

12. Cluster-polypuses propagate by dividing in the middle: *arm*-polypuses do not multiply in this manner. They bring forth their young almost as a tree shoots forth its branches. A little bud appears on the side of the polypus. Do not suppose that this bud contains a polypus, as the vegetable bud comprizes a branch: it is itself the polypus in its growth. It increases in size and length, and at last separates from its mother. Whilst it is united to her, they both compose one body,

as the branch with the tree. You are to understand this in the strictest sense. The prey which the mother swallows, passes immediately into her young, and imparts the same colour to it. So that the whole consists of one little bowel in a great extent. The prey which the young one seizes (for it fishes for it as soon as it has arms) passes in like manner into the mother. They nourish each other reciprocally.

There is scarcely any polypus without buds. All of them therefore are so many polypuses, or so many shoots that grow on a common trunk. Whilst they are unfolding, they themselves send forth smaller shoots, and these smaller still. They all extend their arms on both sides. You think you are beholding a very bushy tree. The nourishment received by one of these shoots, is soon communicated to all the rest, and to their common mother; the chief of the society and the members are one. The society is dissolved by little and little, the members separate themselves, are dispersed, and each shoot becomes in its turn a little genealogical tree.

Such is the natural method by which the arm-polypus multiplies. It may also be multiplied by slips. There is no need to mention, that when it is cut in pieces, each piece in a short time becomes a perfect polypus. It were better to say at once, that the polypus, after being cut into small pieces, rises again from its ruins, and the little fragments yield as many polypuses. Being cut either in length or width, this extraordinary animal is reproduced in the same manner, and the sources of life are equally inexhaustible.

13. But the following is what fable itself has not presumed to invent: bring to their trunk the heads that have been struck off, they will reunite to it, and you will restore to the polypus its head. You may also, if you think proper affix to it the head of another polypus. The mutilated parts of the same or different polypuses, when placed end to end, will unite in like manner, and form only a single polypus.

What have I hitherto said? There is scarce any miracle that may not be performed by means of the polypus; but miracles, when multiplied to so great a degree, hardly appear to be such. A polypus may be introduced by its hind part into the body of another polypus. The two individuals unite, their heads become ingrafted into each other; and the polypus, which at first was double is converted into a single polypus, that eats, grows and multiplies.

I have compared the polypus to the finger of a glove: this finger may *be turned inside out*: so may the polypus likewise, and being so *shifted,* can fish, swallow, and multiply by slips and shoots.

It will be easily believed that the polypus does not like to remain thus shifted. It makes an effort to regain its former position, and frequently succeeds either in part, or altogether. The polypus, which is partly turned back again as at first is a real Proteus, that assumes all kinds of forms; which are all equally strange. Endeavour to represent to yourself the polypus thus turned again. You remember that the insect is made in the form of a bowel. One part of the bowel then is turned backwards on the other; it there fastens and engrafts itself. In that case the polypus is as it were doubled. The mouth encompasses the body like a fringed girdle; the arms are the fringe. They then point towards the tail. The fore-part continues open; the other is usually shut up. You expect no doubt to see a new head and new arms to grow out of the fore-part; which you have observed in all the polypuses that have been divided transversely. But the polypus combines itself a thousand different ways, and each combination has its consequences, which experience alone can discover to you. The fore-part closes itself; it becomes a supernumerary tail. The polypus, which at first extended in the right line, is curved more and more. The supernumerary tail lengthens every day. The two tails resemble the feet of a pair of compasses. The compasses are partly open. The ancient mouth is at the head of the compasses. This mouth which is fastened to the body, and embraces it like a ring, cannot discharge its functions. What then must become of the unfortunate polypus with two tails and without a head? How will it be able to live? Do you think that you have taken nature at unawares? You are mistaken. Towards the upper part of the polypus, near the ancient lip, there are forming not only a single mouth, but several; and this polypus, concerning which you enquired a minute ago how it could exist, is now a species of hydra with several heads and mouths, and devours with all these mouths.

14. What a multitude of physiological truths, that were unknown to us in the vegetable kingdom, has the *arm*-polypus alone unveiled to us? How do these truths appear as paradoxes, and yet how evidently are they demonstrated? Who can doubt now that there exists an animal, a very animal, since it is extremely voracious, whose young grows like branches, and which being cut to pieces and actually minced, regenerates anew in all its parts, and even in the smallest fragments, that may be grafted by *approximation* or *inoculation*, turned inside outwards like a glove, afterwards cut, turned back and cut again, without ceasing to live, devour, grow, and multiply.

It was not a fit season therefore to make *general rules*, to arrange nature, establish distributions, form systematical orders, and to raise an edifice, which future ages, better instructed, will even dread to project. We have scarce any knowledge of the animal, when we would undertake to define it. Because our knowledge is at present in some measure improved, shall we presume to think we thoroughly know it? Polypuses have astonished us, because on their first appearance there was no idea in our brain analogous to them, and we had taken great pains to discard from it the very possibility of their existence. How many animals are there that are even more strange than polypuses, and that would confound all our reasonings, could we discover them? t would be necessary on that occasion to invent a new anguage, in order to describe our observations. Polypuses are placed on the frontiers of another universe, that will one time or other have its COLUMBUS's and

VESPUTIUSES. Shall we imagine that we have penetrated into the interior parts of the continents, because we have taken a slight view of some coasts at a distance? We will form to ourselves more exalted ideas of nature; we will consider her as one immense whole, and will firmly persuade ourselves that what we discover of her is but the smallest part of what she contains. Having been heretofore astonished, we will forbear being so for the time to come, but will continue our observations; we will amass fresh truths, connect them if we are able, and be in expectation of every discovery, because we will continually say, that the known cannot serve as a model for the unknown, and that models have been varied *ad infinitum*. *Cluster*-polypuses multiply by dividing themselves; who can tell but that there may one time or other be discovered animals, that instead of dividing themselves, may unite together, and join themselves to one another, in order to compose one single animal? Or who knows whether the multiplication of such an animal may not have as an essential condition, the consolidation of several animalcules in a single one? We say that an animal must have a brain, a heart, arteries, veins, nerves, a stomach, &c. These are the ideas we have deduced from large animals, and we carry them every where with confidence. We act herein like a French traveller, who should expect to find in the *Terræ Australes* the modes of his own country, and that would be greatly chagrined on being disappointed. The animal kingdom has also its *Terræ Australes*, in which probably it is not customary to meet with a brain, a heart, a stomach, &c. Why do we desire that nature should always condescend to form one animal with the elements of another? She might indeed be constrained so to do, did not her fecundity surpass that of our poor conceptions? But the HAND, which has formed the polypus, has demonstrated to us, that IT can, when necessity requires, *animalize* matter at a much less expence. IT has descended by almost insensible degrees from those great organized masses we call quadrupeds, to those minute organized bodies we stile *insect*; and by gradual and skilfully contrived subtractions, it has at length reduced animality to her smallest terms. We are unacquainted with these smallest terms. The polypus, simple as it appears to be, is without doubt very much compounded, in comparison of such animals as are placed beneath it in the scale. It is, if we may be allowed the expression, too much an animal, to be the last term of animality. We know that the brain is the principle of the nerves, that it filtres the spirits; that the nerves are the organ of feeling; that the heart is the primum mobile of circulation; that the veins and arteries are the dependancies, all this we have seen in great animals, we have again to our surprise found it in insects: though under different forms: we were thus accustomed to regard these various organs, and some others, as essential to the animal. The polypus, however, exhibits to us nothing similar; the best miscroscopes only discover to us an infinite number of small disseminated seeds in its whole substance; and the unforeseen experiment of its *shifting*, sufficiently proves that there is nothing in its structure common to that of animals before known to us. Were we not capable of imagining, that an animal had been endued with the property of being propagated and grafted like a plant, it would have been much less possible for us to suspect that there had been granted to it the power of being turned inside-out like a glove. The *arm*-polypus, is nevertheless a perfect animal; its voracity is excessive; it devours all the little insects that happen to touch it, and seizes them with such skill, as seems to give it an affinity to hunting animals. The *cluster*-polypus, quite differently constructed, has not the same advantages, but has relative ones: it can excite a rapid motion in the water which brings towards it those living corpuscles it feeds upon. There are undoubtedly many animals that are still much more disguised than the *cluster*-polypus, and by not affording us any *exterior* sign of animality, leave us for a long time uncertain of their true nature. When a *bulb* of such a polypus is detached from it and fixes it by its short pedicle to any support, should we be apt to consider it as an animal production: has not the *gall-insect* been taken for a real vegetable gall-nut by such observers as had not seen it in its primitive state? Is not the pond muscle deficient in many things we judge to be necessary for the animal? How many shell-fish are still farther degraded? Nay more, there may probably exist some animals, which it would be impossible for us to acknowledge as such, even though their whole structure, as well internal as external, should be laid open to us; the reason is, that judging only according to our present notions, we cannot deduce from this structure the opinion of life.

15. I cannot yet quit this subject. We are not able to conceive all the methods by which the AUTHOR of nature has given life and sensation to a prodigious number of different beings. Let us judge of them at least by a comparison of a small number of animated beings we are acqainted with. How greatly does life differ in the ape and bell-polypus? What intermediate degrees are there betwixt these two terms? Perhaps there are still more from this polypus to the last of animals. I do not examine if souls have been varied like bodies; but I conceive that organized matter has been modified infinite ways, to which have corresponded as many different methods of participating life and sensation. I likewise conceive that the same soul, if placed successively in all the organized bodies that exist, would successively experience all the possible modifications of life and sensibility. This soul would pass through all the degrees of animality; and if she could remember them all, and compare them, she would equal the superior intelligences in knowledge. She would contemplate our world through all those glasses that have been given to the various beings that inhabit it.

16. Let us draw a general consequence from all this: that *analogy*, which is one of the great lights of physics, is not capable of dissipating the shades of it. This light is frequently extinguished on the approach of certain bodies which we bring to the touch of experiment. To what purpose does analogy serve in the examination of the *bulb*-polypus? We cannot even define these *bulbs*;

and does the name we give them express any thing more than mere appearances? How can analogy enlighten us concerning the nature of these minute bodies, and the manner by which they are engendered and ingender, whilst she offers nothing to us either in the vegetable or animal kingdom, which bears the least relation to these productions, so different from all those that were known to us? I affirm as much with regard to the natural division of the *bells*, and of the *shifting* of the arm-polypuses. This is an entire new order of things, which has its particular laws, which we should in all probality be able to discover, could we find some means of penetrating into the secret mechanism of these little beings. We should then discern all the sides by which they are connected with other parts of the organical world.

17. When we consider in a general view the composition of men and quadrupeds, we shall presently discern that there is with respect to all of them the same foundation of structure, differently modified in different species. In order to be convinced of this, we need only cast our eyes on those anatomical plates, in which are represented the skeletons of divers animals that have been dissected. From man, the ape, and horse, to the squirrel, weasel, and mouse, we shall see throughout the same design, the same arrangement, the same essential relations, except in a few particulars. The spine, which is formed of a series of parts, joined to each other as by so many hinges, bears to its upper extremity a sort of bony box, of greater or less extent. Some bony arches, which on one side are connected with the spine, and on the other with a part opposite to it, form another more spacious box. The upper and lower extremities are joined likewise to the spine by different interposed bands; and maintain the body in those various attitudes its exigencies require. This economy is so generally observed, that it has even been remarked that the vertebræ of the neck are seven in number in all the species. Almost the same order is to be met with in birds and fishes. It varies more and more in reptiles, shell fish, and insects. The latter however have their bones, se-

veral parts of which seem to imitate the corresponding ones in great animals; but whereas among the latter the flesh covers the bones; on the contrary, among insects the bone covers the flesh. In this numerous class of little animals, nature has in an especial manner *diversified* her models the most, and displayed the wonderful fecundity of her inventions. In the large parts of the animal kingdom she pretty nearly pursues the same plan of architecture, and hardly diversifies any thing but the orders. In one we beheld the strength and majesty of the *Tuscan*; in others the elegance and delicacy of the *Corinthian*. But when she descends to insects, she seems entirely to change her plan, and to retain as little as possible of her first models. She seems at length to abandon them altogether in her formation of an *arm* or *bell*-polypus. She constructs plants on still different models; but these models retain in them something of the organization of animals, and particularly that of insects. The organs of respiration are almost the same in the plant and insect. Those parts which are essential to life are dispersed throughout the whole body of the plant, as they are in insects, that are reproduced by slips. Those plants which appear to be most elevated in the scale, exhibit to us a stalk, branches, roots, leaves, flowers, and fruit. A swine-bread, an agaric, a liver-wort, on the contrary, are so extremely disguised, and have in them so small a resemblance to plants, that it is necessary to have the eye of a strict observer, in order to know and characterize them. These half vegetable productions, if I may be allowed the phrase, seem, in the vegetable kingdom to be what the gall-insect, polypus, and the muscles are in the animal. They do not appear to be more organized than an amianthus, a talc, or a crystal.

18. The distance however is much greater from the most regular fossil, or that most resembling a vegetable, to the plant in the least degree so, or that is the least organized. The fossil does not *grow*, properly speaking: it does not receive *nourishment*, nor engender.

It is formed of the successive *apposition* of different molecules, which, by uniting together under certain relations, determine its figure. The plant is a body truly organized, which of itself works the molecules, destined to incorporate themselves with its substance, and to extend it every way, and contains little bodies resembling it, which it nourishes, causes to expand themselves, and by means of which it multiplies its being: nature then seems to make a great chasm in passing from the vegetable to the fossil, &c. There are no bands, no links, hitherto known to us, which unite the vegetable to the mineral kingdom. But shall we form our judgment of the chain of beings by our present degrees of knowledge? Because we here and there discover in it some interruptions, some void spaces, shall we conclude from thence that they are real? Shall we imagine that a comet has split the scale of our world, and destroyed the harmony of it? We are only beginning to survey the vast cabinets of nature; and amongst that innumerable multitude of various productions which she has assembled, how many are there which we have not so much as seen, and can frame no idea of their existence? Shall we hasten to decide concerning the result of these productions before we have examined them all, or formed an exact list of them? The vacancy we suppose left between the vegetable and mineral, will in all probability be one day supplied. There was a similar void betwixt the animal and vegetable: the *polypus* now fills it up, and sets in a conspicuous light the admirable gradation there is among all beings. It is true we cannot form any *mean* idea betwixt the plant and the fossil; we do not imagine there is any shadowing between *growth* and *apposition*; but had we formed any conception of the properties of the *polypus?* If those marine productions, which have been called *stony* plants, were real plants, they were in some measure one of the links requisite for uniting the vegetable to the mineral kingdom; but late discoveries have informed us, that these pretended plants are only works of certain polypuses, that have the art of constructing cases for themselves. Those coral flowers, so much celebrated, were real polypusses, and this is another truth wherewith the polypus has enriched the physical world.

19. Organized bodies are tissues which are more or less fine pieces of net-work, or pieces of stuff, whose *warp* itself forms the *woof*, by an art which we should think we could never enough admire, were we acquainted with it. *Fossils* are a kind of *inlaid* work: we do not know where the organization ends, nor which is its smallest term: but by ceasing to organize, nature does not cease to dispose or arrange: she even seems to organize when she has made an end of doing so. One would be ready to imagine that *fibrous* and *leaved* stones were vegetables in part disguised. The constant regularity of *salts* and *crystals* strikes us in an equal degree. We may be assured that the crystal is formed of the repetition of an infinite number of small, regular, and pyramidal bodies, properly laid on each other, which represent, in some measure, the whole exactly in miniature. We should, notwithstanding, be very much mistaken were we to consider these little pyramids as the *germ* of the crystal; it is, strictly speaking, no more than an *element*, or constituent particle of it: it does not unfold itself, it remains as it was; but it serves as a support to other similar pyramids which are to be joined to it, and thus to augment the crystaline mass by successive *aggregates*. The crystaline juice is not received, wrought, and assimulated by strainers or vessels that are more or less fine, or more or less folded together, within the pyramid; it is already entirely prepared when it procures the union of different molecules into one pyramidal mass, by virtue of the laws of motion and attraction. This is the primary character which distinguishes brute from organized bodies, a character which we ought never to lose sight of when we compare together beings of these two classes.

20. Thus the bodies of plants and animals are species

of *looms*, machines more or less compounded, which convert into the proper substance of the plant or animal the various matters subjected to the action of their springs and liquors. These machines, which are so superior in structure to those of art, seem still more so when compared in their essential effects. Those matters which organical machines work, they likewise *assimulate* and incorporate with themselves; they *grow* by this incorporation, augment in their dimensions every way, and during their growth, all their parts preserve among themselves the same relations, the same proportions, the same exercise; all continue to discharge their proper functions: the machine remains, in its extended state, what it was in miniature. It is a system, a wonderful assemblage of an almost infinite number of tubes, differently formed, calibered, and interwoven, that like so many filtres, purge, fashion, and refine the nutritious matters. Each fibre,—what am I saying? each fibrilla is itself a machine in miniature, which, by performing analogous preparations, appropriates to itself the alimentary juices and gives them the arrangement suitable to its form and their functions. The whole machine is in some measure only the repetition of all these *lesser machines*, whose united strength conspires to the same general end. The excellence of organical machines appears, in a conspicuous light, from other still more striking instances: they not only produce, from their own foundation, machines similar to them, but a great number of them reproduce of themselves those parts they had been deprived of, which various parts become afterwards as many machines, equally perfect with those whereof they before only made a part.

21. To conclude: the same general design comprizes all parts of the terrestrial creation. A globule of light, a molecule of earth, a grain of salt, a particle of mouldiness, a polypus, a shell-fish, a bird, and a quadruped, man, are only different strokes of this design, and represent all possible modifications of the matter of our

globe. My expression falls greatly beneath reality: these various productions are not different strokes of the same designs, they are only so many various points of a single stroke, that by its infinitely varied circumvolutions, traces out, to the astonished eyes of the *cherubim*, the forms, proportions, and concatenation of all earthly beings. This single stroke delineates all worlds, the *cherub* himself is a point of it: and that ADORABLE HAND which drew this stroke, alone possesses the method of describing it.

CHAP. IX.

Continuation of Animal Economy considered in Insects.

1. IN the seventh chapter you have seen the *earth-worm* regenerate; you have contemplated the progress of this regeneration; you have remarked a little bud that grew at the fore-part of the stump, which, unfolding itself by degrees, became a vermiform appendage, a kind of little worm, that seemed to be engrafted on the stump.

This animal bud has discovered to you the first origin of the part that is reproduced. You have perceived that it was lodged in miniature under the fleshy parts of the stump, and that the latter does not contribute more towards this production than the earth does to the plants that have taken root in it..

Thus the earth-worm contains, like the polypus, a multitude of germs, which begin to unfold themselves as soon as certain accidents convey towards them the nutricious juices. The sources of reparation are here in proportion to the accidents that may threaten the animal. But the reproduction of the earth-worm is much more astonishing than that of the polypus: it is not only an enormous colossus in comparison of the polypus, but its structure is also much more compounded. It affords a more numerous aparatus of viscera, vessels, trachæ, muscles, &c. It has real blood, and this blood circulates. But it is besides an *hermaphrodite*; it unites at once all the organs peculiar to the two sexes. This insect, which in appearance is the most contemptible, would alone be sufficient to exhaust the sagacity of the ablest observer, though applying himself solely to the contemplation of it. What a gainer would physiology be from such an enquiry! What a number of truths, concerning which we should have no doubt, would then augment the treasures of our physical knowledge!

2. The regeneration of fresh water worms presents us with the same phenomena as that of the earth-worm, and their structure is likewise very much compounded. Several species of them are principally distinguished by their colour: all of them do not possess, in the same degree, the property of multiplying by *slips*. In general, the polypus greatly surpasses them in this respect; perhaps, because its structure is more simple; and it may also be owing to its having a more ample provision of germs. Be that as it may, when we cut off the head or tail from the worms we are treating of, they do not themselves become worms, but all, or the greatest part of the intermediate pieces, how small soever they be, very easily regenerate themselves, and in a short time produce an equal number of complete worms.

Regeneration begins by a little puffing up of the anterior extremity; this puffing seems analogous to the vegetable roll: the wound closes, and quickly consolidates: a little bud appears in the centre of the roll: this bud increases in size and length by degrees. New rings and new viscera begin to appear. You see from the rest what is to follow.

You also very easily comprehend after what manner each piece vegetates of itself: it has in miniature the same viscera as the whole exhibited at large. You have not forgot that the parts essential to life are here dispersed throughout the whole body, and that circulation is performed in the smallest pieces as in the whole worm

Little buds, or tubercles, sometimes rise on the bodies of these worms, and give room to think that they are young ones growing from them; *slips*, resembling those of the polypus, having the same origin and end.

This species of worm, from certain pieces of which a tail shoots forth in the part where a head should have been produced, affords a very singular phenomenon, which the frequency of it does not permit us to consider as the mere effect of chance. It also proceeds less from chance than the production of this supernumerary tail. It is too well organized not to have the same origin as that which shoots forth at the posterior extremity: but we cannot pretend to say what are the causes which here determine a tail to take the place of a head: we only know, that this kind of worm is very much exposed to the loss of its hind part; it is therefore, in all probability, furnished with more means for repairing this loss, than that of the fore part.

3. It would seem as if nature had proposed to herself a kind of diversion in the formation of insects: she has lavishly bestowed on them members and organs, which she has distributed but sparingly to other animals; to one she gives two hundred legs, to another twenty thousand eyes, to a third several hundred lungs, &c. The production of new legs, new rings, a new head, and a new viscera, seem in these instances to be attended with no greater labour or difficulty than the production of new hairs or new feathers.

She often likewise disguises the same insect, and presents it to us successively under such opposite forms, that they seem to compose so many distinct beings: this leads us to the *metamorphosis* of insects.

4. We have had frequent occasion to acknowledge, that the proceedings of nature are not always uniform, and that she can accomplish the same end by very different ways. Look at this little oblong, black, smooth, and shining cone: it most resembles those cones which many insects construct to metamorphose themselves in: however, it differs from them in some essential parti-

culars. View it through a microscope, you will then perceive in it some annular incisions, but not very deep, which discover to you its true nature, and at the same time informs you, that it is nothing but the skin of a worm which has become round, and has contracted a hardness. Open it gently with the point of a needle, you find nothing in it but a kind of pap, in which you are able to discover nothing. The insect has but lately lost its form of a worm; how has it been reduced into that soft substance? How will that become an insect? Suspend your questions, and open a cone that is less recent than this. What do you discover in it? A little mass of oblong, whitish flesh, in which you cannot perceive, even through a magnifying glass, the least signs of members or organs. In a word, you have before you an *oblong ball.* Do not imagine that this ball is a case that contains a nymph, it is itself a nymph that is much disguised. Press the ball a little: the legs begin now to shew themselves; they come out of a little socket, that is at one of the extremities of the ball. Augment the pressure by degrees, you will force all the parts of the nymph to appear: they therefore exist already, but they were sunk and infolded within the ball, almost as the fingers of a glove might be in the hand of a glove.

If you could make the same experiment on the *oviform* bodies of *net*-polypuses, and on the buds of *arm*-polypuses, that you have lately made on the *oblong ball,* you would probably oblige the little polypus to produce itself, and by that means accelerate the time of its birth.

5. Insects that pass through the state of an *oblong ball* can therefore form themselves a cone of their own skin. All the parts of the nymph separate themselves by little and little from this skin; it grows round and hard about them: and under this singular arch they make an end of perfecting themselves: they are at first only of the consistence of a pap: this thickens by degrees; it assumes the form of an oblong ball, and when all the members of the nymph have acquired a

certain consistence, they issue one after another from the inside of the ball, and arrange themselves like those of other nymphs.

By becoming a kind of cone, the skin of the insect does not lose in all the species, the form that was proper to the worm; some of them preserve it so well, that the metamorphosed worm scarcely differs at all from the worm that has not been yet transformed.

6. A hen that should lay an egg as large as herself, from which a cock or a hen would be hatched, may offer to us such a prodigy, as we should find some difficulty in believing. A fly that is troublesome to horses, and whose form has caused it to be named the *spider-fly*, affords us such a prodigy; and it should not seem the less strange because it takes place only in an insect. Were there a law in the organical kingdom, to which we knew no exception, it would assuredly be that which ordained every organized body to grow after its birth. Nevertheless, here is a fly that lays a species of egg, from which is produced another fly as large and as perfect as the mother. This egg is almost round, white at first, and afterwards of a black or ebony colour. The shell is firm and polished—but I must undeceive my reader: this is not a real egg, but has only the appearance of one; it is the insect itself that has assumed the form of an *oblong ball* in a cone made of its own skin. The thing is not the less wonderful on that account. All insects that metamorphose themselves go through their various transformations, out of the belly of their mother. They are, indeed, to grow considerably before they undergo their first transformation, but do not grow at all afterwards. We have then an insect that transforms itself in the very belly of its mother, and acquires no farther growth after it has issued from it.

These cones of the spider-fly, these pretended eggs have been opened at different times, and in them have been found the same things that are discerned in the *oblong ball*-nymphs, when observed at their different ages. Moreover, there have been discerned *stigmata* in this species of cone that might be taken for a real egg, which is an evident proof that it was the skin of a worm that has transformed itself under this very skin. An egg is without motion: our cone has some that are very visible, and, in certain circumstances, the inside admits of their being seen, which attracts the attention of the observer. He seems to discern little clouds that succeed each other without interruption, and that pass with a progressive and uniform motion, from one end of the cone to the opposite one. In the cones that are laid before the time, these shadowy layers have a contrary direction from that which they have in the cones at the full time. You have seen that the circulation varies its course in the nymph: since our shadowy layers change their's likewise, they pretty clearly indicate to us, that the abortive cone is the worm itself, that has not yet gone through its metamorphosis: this worm is, in truth, a very singular being; it has neither head, mouth, nor any member: it is, in appearance, nourished like the eggs of birds, in the *trunks* that enclose them. A nice dissection demonstrates the *ovary* of the fly, and the *worm* lodged in the middle.

7. When animals were divided into *viviparous* and *oviparous*, it was thought that all the species were comprehended. The vine fretter came first to clash with this famous division, and convinced us that an animal was at the same time viviparous and oviparous. The *arm*-polypus next appeared, and presented us with an animal, that, multiplying by *slips*, might with good reason be called *ramiparous*. There have even been observations made which seem to prove that it is likewise oviparous. Another species of polypus, that multiplies also by slips, and is extremely well characterised by a sort of plume, lays real eggs. These eggs may be preserved in a dry place for the space of whole months like *seed* of silk-worms; and if afterwards sown in water, there will be produced from them as many polypuses. The bulb-polypus may be depicted by the epithet of

bulbiparous. But how shall we describe the multiplication of other *cluster*-polypuses, that of the *net*-polypuses, and of the millipes? Lastly, the *spider-fly* presents us with another method of multiplying, in which there is nothing that is common with any of those above-mentioned, and which is attempted to be expressed by the term of *nymphiparous*. How many other methods of propagating will there be discovered every day for which it will be necessary to create new terms?

8. One animal does not differ more from another than a worm from a nymph. And what renders this metamorphosis still more surprising is, that it seems to be performed instantaneously.

What then is the procedure of nature in this respect? She, in other instances, advances by degrees. An insensible developement brings all organized bodies to a state of perfection. Can this law, which is so universal, suffer any exception? A fact which I am going to relate will help us to penetrate this mystery.

Let us confine ourselves to *caterpillars*; they are sufficiently known to us, since the *silk-worm* is a real caterpillar. The caterpillar from time to time changes his skin, and that is common to him and most other insects. These *moultings* are termed *maladies* in the silk-worm, and they are so in effect. But it is very material to observe, that the skin which the caterpiller casts off at each moulting is so complete, that it seems to be of itself a real caterpillar. There is found in it a head, eyes, a mouth, jaws, legs, armed with hooks, stigmata, and generally all the external parts proper to the insect.

How is the caterpillar enabled to divest itself of so many organs, and clothe itself with new ones resembling the first? Nothing can be more simple than this: new organs were lodged in the old ones, as in so many cases or sheaths. In changing its skin, the caterpillar had occasion only to draw them away, and drew them away accordingly, because the cases proved too strait.

This jointing is so real, that it may be perceived by the naked eye. It may even be demonstrated by a very easy experiment. If on the approach of the *moulting*, we cut off the former legs of the caterpillar, she will issue from her spoils without any legs at all. Thus this caterpillar, which we considered as a simple and singular being, was in some measure a multiplied being, or composed of several similar beings jointed into each other, and that successively unfold themselves.

9. Hence arrises a very probable conjecture: may not the *chrysalis* be lodged under the last skin the caterpillar is to cast off? May not this skin be a mask that conceals it from our sight?

A celebrated observer has, by a decisive experiment, assured himself of the truth of this conjecture: he has removed the mask, and has, by this means, discovered the *chrysalis* in a manner very easy to be distinguished. He has seen the six legs of this chrysalis to grow out of the six former legs of the caterpillar, and all the other members of the latter to be wrapped together under different parts of the former.

The *metamorphoses* of insects, then, enter anew into the order of developements, and confirm it. The *chrysalis*, or rather the *butterfly*, for it is in the strictest sense but a swaddled butterfly; the chrysalis, I say, pre-existed in the caterpillar. It does no more than unfold itself in it, and the caterpillar is a kind of machine prepared for performing afar off this developement. It is in some respects, to the chrysalis, what the egg is to the chick.

10. In truth, an insect that must *moult* five times before it is invested with the form of a *chrysalis*, is a compound of five organized bodies, enclosed within each other, and nourished by common viscera, placed in the centre.

As the bud of a tree is to the invisible buds it encloses, so is the exterior part of the caterpillar newly hatched to the interior bodies it conceals in its bosom. Four of these bodies have the same essential structure, and this structure is that which is peculiar to the insect in the state of a *caterpillar*. The fifth body, which is very different, is that of the *chrysalis*. The respective state of these bodies are in proportion to their distance from the centre of the animal. Those that are the farthest off have more consistence, or unfold themselves soonest.

When the exterior body has attained its full growth, the interior, which immediately follows, is considerably unfolded. It soon finds itself lodged in too narrow a compass: it stretches on all sides the sheaths that encompass it. The vessels which convey the nourishment to these coverings being broken or stifled by this violent distension, cease to act. The skin wrinkles and dries up: at length it opens, and the insect appears clothed with a new skin and new organs.

A fast of a day or two precedes each *moulting*. It is probably occasioned by the violent state in which all the organs then are. Perhaps it might be also necessary, in order to promote the success of the operation, and prevent obstructions: be this as it may, the insect is weak after every moulting: all its organs are yet affected by the state they were in under the covering they are just disengaged from. The scaly parts, as the head and legs are almost entirely membraneous, and are all imbued with a liquor that insinuates itself betwixt the two skins, and facilitates their separation. But this moisture evaporates by degrees: all the parts acquire a consistence, and the insect is in a condition to act. The first use that some species of caterpillars, which live only on leaves, make of their new teeth, is to devour greedily their spoils; sometimes they will not even wait for doing it till their jaws have received their full degree of strength. Can these spoils be a proper aliment to renew and increase their strength? Some caterpillars have likewise been seen to gnaw the shells of their eggs after they have issued from them, and even that of the eggs of such caterpillars as have not been hatched.

11. When we have once conceived that all the exterior parts of the same kind are jointed into each other, or laid one on another, the production of new organs has nothing embarrassing in it; and with regard to this, there is not any essential difference betwixt the five moultings that precede the transformation: nothing more is requisite in all that but a simple *developement.*

But it is not absolutely the same, with respect to changes that happen in the viscera before, during, and after the metamorphosis. Here the light that should guide us is almost extinguished, and we are constrained to grope in the dark.

It does not appear that the insect changes its viscera as it does its skin. Those which existed in the caterpillar, exist likewise in the chrysalis: but they are modified, and it is the nature of these modifications, and the manner by which they are performed, which elude our researches.

A little before the metamorphosis, the caterpillar rejects the membrane that lines the inside of the intestinal bag. This bowel, which has hitherto digested gross food, must hereafter digest that which is extremely delicate: the blood that circulates in the caterpillar, from the hind part towards the head, circulates a contrary way after transformation. If this inversion be as real as observations indicate, what idea does it not give us of the changes the inside of the animal experiences? Those, which the circulation of the blood in a new-born infant undergoes, are in a manner nothing in comparison of them.

12. Whilst nature is labouring to change the viscera, and to give them a new life, she is employed, at the same time, in the developement of divers organs, which were useless to the insect while it lived under the form of a caterpillar, and which the new state whereunto it is called renders necessary for it. The better to insure the success of her different operations, she causes the insect to fall into a deep sleep, during which she carries on her work at leisure, and by insensible degrees.

The little wounds, which the rupture of several vessels has occasioned in divers parts of the inside, consolidate insensibly: those parts which had been put into a violent exercise, or whose forms and proportions had been modified to a certain degree, conform themselves gradually to these changes. The liquors, which are obliged to pass through new channels, take that direction by little and little. Lastly, the vessels which were proper to the caterpillar, some of which occupied a considerable place within it, are effaced, or converted into a liquid sediment, which the butterfly rejects after having laid aside the sheath of the chrysalis.

13. When we consider the metamorphosis of insects, we are surprised at the singularity of the means which the AUTHOR of nature has thought proper to make choice of, in order to bring the different species of animals to perfection.

Wherefore is the *butterfly* not bred a butterfly? Why does it pass through the state of a caterpillar, and that of a chrysalis? Why do not all the insects that metamorphose themselves undergo the same changes? Whence does it happen, that amongst the species that assume the form of a *nymph,* some shed the skin of the *worm,* whilst others retain it? How does it also come to pass, that among such insects as pass through the state of the *worm-skin* nymph, some take that form in the very belly of their mother?

These questions, like all those which may be started concerning *essences,* derive their solution from the general system which is unknown to us.

Without endeavouring then to penetrate into the cause of metamorphoses, let us observe attentively the fact, and its immediate consequences.

Let us consider the variety which those metamorphoses disperse throughout nature: a single individual unites within itself two or three different species. The same insect successively inhabits two or three worlds: and how great is the diversity of its operations in these various abodes!

Let us also remark to what degree the relations which the fly or butterfly maintains with the beings that surround them, are multiplied by their metamorphosis. Let us fix our attention on the *cone* of the silk-worm; and admire what a number of hands and machines this little ball sets to work. What prodigious riches should we have been deprived of, had the butterfly of the silk-worm been originally produced in that form!

Insects that undergo transformations, have not ye afforded us any species that multiplies by *slips* and *shoots*. This will not surprise us, when we reflect on the great composition of the bodies of these insects. But let us not be too hasty in our judgment, nor conclude that the property of multiplying by slips and shoots is incompatible with metamorphoses. Nature is too little known to us, to give us a right to form such conclusions. Vine-fretters and polypuses have furnished us with good preservatives against too general conclusions.

CHAP. X.

Parallel between Plants and Animals.

1. IN our researches into the gradual progression of beings, and organical economy, we had frequent occasion to compare vegetables and animals with each other. Let us here collect, in one view, those various marks of analogy which are scattered hither and thither; let us represent them as in a picture, wherein, by a nearer description of them, they will agreeably attract our attention. We will afterwards enquire, if there be any character which essentially distinguishes the *vegetable* from the *animal*.

2. A *seed* is an organized body, which, under various coverings, thicker or thinner, and more or less numerous, contains within it a plant in miniature. A whitish substance, of a spongy nature, fills the capacity of the seed: small vessels, which proceed from the germ, are in every part of this substance, dividing and sub-dividing it. After being laid in the earth, moistened and warmed to a certain degree, the seed begins to shoot up: the moisture, which has penetrated its outward folds, dissolves the spongy substance, and mixes with it. Of this mixture is formed a kind of milk, which being carried to the embryo by the little vessels, furnishes it with a nourishment adapted to its extreme delicacy. The *radicle*, or *little root*, begins, by this means, to unfold itself; it increases in bulk and extent every day. In a short time it becomes sensible of too close a confinement: it makes an effort to come forth. A small orifice, made in the exterior surface of the seed, facili-

fates its egress: the root insensibly sinks into the earth, and derives from thence more substantial and copious nourishment. The small *stalk*, which, till this time, lay hid under the coverings of the seed, now begins to shew itself; the teguments unfold themselves, in order to admit a free passage for it: strengthened by an accession of fresh juices, it pierces through the earth, and advances into the air.

3. An *egg* is an organized body, which, under divers teguments, of various strength and number, incloses an animal in miniature. A fluid matter, of a glutinous nature, fills the inside of the egg: a number of infinitely small vessels spread themselves out in this matter, and are connected with the germ by different branches. Being warmed in a sufficient degree, either by nature or art, the inside of the egg begins to receive life: by means of a gentle heat, the matter surrounding the germ insinuates itself into the small ramifications, from whence it passes into the heart, whose motion it augments: thus the animal becomes a living creature. It increases in size and strength every day, by receiving fresh supplies of more nourishing and perfect juices: after these juices are exhausted, the animal has acquired all the growth it was capable of in the egg. It finds the apartment assigned it to be too narrow: it endeavours to set itself at liberty. Natnre has provided it with an easy method of affecting this, either by arming it with instruments proper for piercing or tearing the coverings which inclose it, or by giving to the egg such a structure as favours its efforts: the animal is produced, and enjoys a new life.

4. The seed then is to the plant what the egg is to the animal. But the plant is not only *oviparous*, but likewise *viviparous*; and the *fetus* is the same with respect to the *animal*, as the *bud* is to the *vegetable*.

Being concealed under the rind, the bud there receives its first growth. It is minutely inclosed in membraneous teguments, analogous to those of the seed: it adheres to the bark by small fibres, which transmit a nourishment to it, adapted to its state. When it has arrived to a certain bulk, it penetrates the rind in order to come forth: at its first appearance, it bears the infolding coverings along with it, from which it is soon released. However, being as yet too feeble to subsist without the aliment provided by the mother, it continues to cleave to her; and cannot, for a long time, be separated without endangering it.

Being lodged in the matrix, the *fetus* there receives its first growth. It is there contained at first in miniature, in the membraneous inclosures resembling those of the egg: it shoots forth small vessels in the matrix, which convey thither the nourishment necessary to promote its growth. When it has arrived to a certain size, it bursts these inclosures, and comes into the world: sometimes these inclosures accompany it at its issuing forth. After it is produced, the little animal is not always able to provide for itself without the assistance of the dam: she must still furnish it with sustenance, which it cannot dispense with the want of for a certain time without danger.

5. The plant is nourished by the *incorporation* of substances received from without: these matters are very heterogeneous. Being pumped by the *pores* of the *roots*, or by those of the *leaves*, they are conveyed into the *utriculi*, where they ferment and digest: they pass into the *ligneous* fibres, which transmit them to the *proper vases*, where they appear under the form of a juice, which is more or less coloured. The ramifications of the proper vases afterwards distribute them into all the parts, to which they are united by new filtrations.

Tubes made of a silvered blade, which are elastic, and turned spirally like a spring, accompany the vessels which contain the sap, in their course. Being appointed for the purpose of respiration, these tubes introduce a fresh elastic air into the plant, which prepares and subtilizes the sap, and probably colours it, besides contributing to its motion: the superfluous matter, or that part which is not so proper to be mixed with the plant, is conveyed to the surface of the leaves, whence it evaporates by an insensible, but very copious *transpiration*. *Globules, vesicles,* or other *excretory organs,* which are distributed among the young shoots or leaves, procure an evacuation of the grosser matter, and such as is of a stronger consistence.

The *animal* is nourished by the *incorporation* of matter which proceeds from without: this matter is very heterogeneous. Being received by the *mouth,* it is conveyed into the *stomach* and intestines, where it undergoes different preparations: it passes into the *lacteal veins,* and their dependencies, or in other like vessels, whereby it is transmitted into the blood-vessels, where it appears under the form of a fluid, more or less coloured, or flowing. The ramifications of the blood-vessels afterwards disperse it into all parts, with which it incorporates itself by new preparations.

Pipes composed of cartillaginous rings, or of a silvered and elastic blade, turned spiral-wise, communicate with the blood-vessels, or follow them in their course. As they are appropriated to *respiration,* they introduce to the animal a fresh and elastic air, which prepares, attenuates, and probably colours the blood, contributing likewise to its motion. The superfluous matter, or such part of it as is improper to be united with the animal, is carried to the surface of the *skin,* from whence it evaporates by an insensible, but very copious *transpiration. Glands,* or other *emunctory organs,* placed in different parts of the body, procure the evacuation of the grosser matter.

6. The *plant grows* by *unfolding,* or the gradual extension of its parts in length and width: this extension is followed by a certain degree of hardness, contracted by the fibres. It diminishes as the hardness increases:

it entirely ceases when the fibres are so far hardened as not to yield to the *force* which tends to enlarge their surface.

The plants which become hardened the latest, are those which are the longest time in growing. *Herbs* grow and harden faster than *trees*: some of them cease to grow at the end of a few weeks, or even a few days. Among the last, some continue to grow for a great number of years, and even for ages.

We observe analogous differences between individuals of the same species: some harden sooner, grow in a less degree, or continue smaller; others harden later, and become larger.

The bud has nothing *ligneous* or woody in it: being *herbaceous* in every part of its substance, it becomes ligneous by degrees. Its stalk is formed of a prodigious number of concentric blades one in another, which are disposed according to its length, and compose different bundles of fibres, which are themselves formed of a prodigious number of lesser fibres.

At the centre of the stalk is placed the *pith*; and the spaces which are left between the blades, are likewise filled with a pithy substance.

From the thickness of the blades results its growth in width; from the lengthening of the blades its growth in length proceeds: all the blades grow and harden one after another: every blade grows and hardens alike successively throughout its whole length. That part of every blade which grows and hardens first of all, is that which composes the base of the stalk: the blade which grows and hardens first is the innermost, or that which immediately encompasses the pith. This blade is again covered with another, which being more ductile, extends itself the more: a third blade incloses this last, which, as it hardens still later, is a longer time in its growth; the case is the same with regard to a fourth, fifth, or sixth. All these, thus diminishing in thickness, and inclining towards the axis of the stalk as they approach its upper extremity, form so many little cones engrafted into each other, from whence proceeds the conic figure of the stalk and branches.

From the assemblage of little cones which become hardened during the first year, is formed a cone of a woody nature, which determines the growth of that year. This cone is inclosed in another herbaceous cone, which is only the rind, and which, the following year, will produce a second ligneous cone, &c.: when the wood is once formed, it does not extend itself any farther; so that in *cicatrices*, *grafts*, and different kinds of tumours, the rind is the only part that is employed. By stretching, thickening, or swelling itself, the rind insensibly forms a *roll*, and produces excrescenses which are more or less considerable, in proportion to the ease with which it is distended, or according to the quantity of juices it receives.

7. The *animal* grows by *expansion*, or by the gradual extension of its parts in every sense: to this extension there succeeds a hardness in the fibres. The extension diminishes as the hardness increases. It ceases when the hardness has arrived to such a pitch, as not to admit of the fibres giving way to the force which contributes to enlarge their coats.

Those animals in which this hardness is formed latest, are longest in their growth. *Insects* grow and harden in a much less time than *great animals*. Some of them cease growing at the end of some weeks, and sometimes in a few days: of the latter some continue growing for a great number of years, and even some ages.

One may observe analogous differences in the growth of individuals of the same species; some of which, that harden later than others, acquire a greater bulk.

The *fetus*, in its original state, contains nothing of a bony nature. As it is *membraneous* throughout, it only becomes *bony* by degrees. The bones are composed of a prodigious number of blades, folded in each other, lying according to the length of the bone, and forming various collections of *fibres*, which are themselves composed of the re-union of a great number of *little fibres.*

In the centre of the bone is placed the *marrow.* The spaces left between the blades are filled with a *medullary substance.*

From the thickening of the blades the growth of the bone proceeds, from the lengthening of them, their extending in length; all these blades grow and harden after one another: each blade grows and becomes hard in a like successive manner throughout its whole length. That part of the blade which grows and hardens first, composes the body of the bone, which immediately encloses the marrow. This blade is again covered with a second, which, being more ductile, stretches itself in a greater degree. A third blade again infolds this, which, as it hardens later than the others, is a longer time in its growth. It is the same with respect to a fourth, fifth, or sixth. As they all thus diminish in thickness, and detach themselves from the axis of the bone, the nearer they approach to its extremities, they form so many little columns, infolded within each other, which increase in diameter at their extremities. From hence we deduce the figure peculiar to *long bones.*

The growth of the bone during the first year is attributed to the number of blades which become hardened in that year. This bone is covered over again with a great number of *membraneous* blades, that bear the name of *periosteum,* which, as they gradually extend and harden, conduce to the increase of the bone in every part of it. The bone, when it is once formed, extends itself no farther.

Thus, in *fractures, anchyloses,* and the different species of excrescences, whether natural or accidental, the *periosteum* is the only part of the bone that labours. By stretching, thickening, and swelling itself, the *periosteum* restores the bone, insensibly, produces a callosity, and forms greater or less tumors, in proportion to the facility wherewith it extends itself, or as it is more or less supplied with juices, or with such as are more or less viscous.

8. The dust or fine powder of the *stamina* is the principle which fertilizes the seed. The pistil is the place where this fecundation is performed.

Being contained in certain *vesicles*, the *fecundating dust* is discovered in them by a microscope, under the appearance of a group of minute, regular bodies, for the most part of a spherical or elliptic form, which, being moistened, open themselves, and emit a thin vapour, in which there floats a great number of exceeding small seeds, which seem to move on all sides. The dust itself, when put into a drop of water, moves several ways with great rapidity.

The *pistil* is composed of three principal parts, the *base*, the *cups*, and the *top*. The *base* contains one or more cavities, where the grain is lodged. The *cups* are long tunnels, whose base or aperture is turned towards the *top*: This is generally furnished with several *nipples*, each of which is *perforated*, having their diameter corresponding with that of a small grain of the dust.

Being in the lower part of the cup, the minute grains are pressed in them more and more by the straitness of these pipes: they are therein moistened with a juice that lines their sides: they open themselves and eject the *seminal vapour*, which penetrates to the *seed*, and promotes fecundation.

Several species of plants have two sorts of individuals: viz. 1. Such individuals as only bear *stamina*, and these are males; and two individuals that have only the *pistil*, which are females.

In a great number of species every individual is an *hermaphrodite*, which unites both *sexes*, the *stamina* and the *pistil*. Sometimes this union happens in the same flower, then the *stamina* surround the *pistil*: at other times it is only effected on the same *branch*; so that the *stamina* are placed on one part, and the pistil on another.

9. The *seminal liquor* is the principle of *fecundation*

in the *egg*: the *matrix*, or ovaries, are the places where it is performed.

Being enclosed in the *seminal vessels*, the fecundating liquor appears in them, through a microscope, like a mass of small regular bodies, of different lengths, which seem to separate themselves into a great number of extremely minute grains, moving different ways. Sometimes these corpuscles resemble cases with springs, which, when moistened, open themselves and dart forth a limpid matter, abounding with a great number of very small grains.

The *matrix* consists of three principal parts, or dependencies; the *fundus*, or bottom, the fallopian tubes, and the ovaries. The *fundus* contains one or more *cavities*, in which the *embryos* receive nourishment and expand themselves: it has an *orifice* in the fore part. The fallopian tubes are a kind of long funnels, whose aperture is directed towards the *ovaries*, where it ends. The *ovaries* are a mass of *vesicles* that are real *eggs*.

When the most subtle part of the seminal liquor has arrived through the fallopian tubes to the ovaries, it there fecundates one or more eggs. These afterwards descend by these tubes into the matrix, where they are fixed and unfold themselves. In *oviparous* females the eggs are contained in a kind of bowel, wherein they receive their growth; the seminal liquor makes them fruitful.

Most animals consist of two sorts of individuals, *male* and *female*; but there are other species, of which every individual is an *hermaphrodite*, which unites the two, although it cannot fecundate itself. In some species, where a distinction of sexes is observed, there is no coupling, properly so called: the *male* only communicates his liquor to the eggs which the *female* has deposited. Finally, some species are propagated without any apparent or external fecundation.

10. A plant does not only *multiply* by *seeds* and buds; it is likewise propagated by *suckers* and *sprigs*. It may also be multiplied by *slips* and by *engrafting*.

A tree sends forth small buds from various parts of its surface: these buds increase in bulk, they open and disclose the *shoot*, which extends itself every day. While it is expanding itself, other still smaller sprigs shoot from it: these, in their turn, are succeeded by lesser ones, all of which are so many trees in miniature; and the nourishment received by one of these sprigs is communicated to the whole plant.

When it has attained to a certain size, and is separated from the trunk either by nature or otherwise, these shoots sustain themselves and become so many distinct trees. Being cut into pieces according to their width, or even their length, these shoots will grow again of themselves and will become as many trees as they were made slips of. The leaves themselves, when separated from their shoots, may afford so many complete plants. Being fastened closely to each other, or *inserted* in one another, several of these shoots, whether taken from the same or from different individuals, will unite together in so intimate a manner, that they will receive reciprocal nourishment, and form one individual whole.

The animal is not only *propagated* by *eggs* and living young, but likewise by shoots. It may also be multiplied by *slips* and *ingraftings*. A polypus sends forth little *buds* from different parts of his body. These buds grow big and lengthen insensibly: every one of them is a young shoot: while it is unfolding itself, there springs from it other smaller shoots: these, in their turn, produce smaller still. All these shoots are so many little *polypuses*, and the nourishment one of these *polypuses* receives, is communicated to their whole number. When they have arrived to a certain size, they separate themselves from the trunk, and become so many individuals.

Being cut into little bits, either transversely or lengthwise, the polypuses grow up again from the ruins, and become as many complete ones as they were pieces. The very skin, or even the least fragment of them is capable of affording one or several *polypuses*.

11. The *generation* of *vegetables* is not constantly regular: the laws by which they operate are sometimes infringed: from them arise various species of monsters: sometimes they are compounded leaves, whose smaller ones are more or less numerous, or more irregularly shaped, or distributed with less symmetry than usual. Sometimes there are flowers which have neither *stamina* nor *pistils*, and whose *petals* being greatly multiplied, seem to have absorbed these essential parts. Sometimes two fruits cleave together by a natural *graft*, or are enclosed in each other. Sometimes there are *flowers* or *fruits* whose form differs widely from that which is peculiar to the species. Lastly, There are productions which do not properly belong to any particular species, because they derive their original from seeds that have been fecundated by *dust* of a different species.

The *generation* of *animals* is not constantly *regular*: the laws by which it is governed are sometimes disturbed; whence are produced the different species of *monsters*. Sometimes there are *hands* and *feet*, whose *fingers* or *toes* are fewer or more in number, or formed in an irregular manner, or otherwise disposed than usual. Sometimes there are *fetuses*, in which the parts of *generation* are obliterated. Sometimes there are two eggs or two *fetuses* that cleave to each other by a natural cohesion, or that are contained in one another. Sometimes there are *eggs* or *fetuses* whose form is greatly different from that which is peculiar to the species. Lastly, there are productions that partake of two species, because they are produced from such females as are fecundated by males of different species.

12. The laws respecting the nutrition and growth of vegetables are liable to greater disorders than those of

generation. From hence are derived the different kinds of maladies the *plant* is subject to. Some of these *maladies* only attack the leaves, and produce on them *spots* of different colours, *wrinkles, pustules, scabs*: others attack the principal *viscera*, and occasion *choakings, obstructions, stagnations, tumours, cancers, effusion*; others take their seat in the *flower* or *fruit*; others affect the *ligneous* bodies, which they cause to moulder away, whilst the bark remains whole; others come from little plants or divers insects, which being on the outside or inside of vegetables, convert their nourishment to their own advantage, or change the organization of it. Others derive their origin from a change of climate, aliment, or culture.

The laws of the nutrition and the growth of animals are more frequently disturbed than those of generation. From hence proceed the various species of *disorders* to which an *animal* is exposed: among these maladies, there are some which attack only the *skin*, and produce *spots* of various colours, *wrinkles, pustules, pimples*: others attack the principal bowels, and occasion *oppressions, obstructions, stagnations, tumours, abscesses, overflowings*: others are seated in the *organs of generation*: others seize the bones, and beget *rottenness* in them, whilst the *periosteum* continues sound: others have their source from different insects which, being lodged either without or within the animals, divert the nourishment of them to their own benefit, or alter the constitution of them: others are caused by the change of climate, nourishment, or breeding.

13. Finally, the *plant*, after having escaped a variety of maladies which threatened its life, cannot elude the effects of *old age*, that creeps into it, nor the stroke of *death*, the inevitable consequence of it. Being hardened by time, the vessels lose their exercise, and are stuffed up: the liquors contained in them no longer move with the same facility, nor continue to be filtrated and pumped out with the same precision: they stagnate and corrupt, and this corruption, being soon communi-

cated to the vessels that enclose them, the vital functions cease, the plant dies, and crumbles into dust.

Lastly, the animal, after having been preserved from those diseases which conspired against him, cannot escape *old age,* nor death that follows in his train.

When the vessels are grown hard through time they lose their action, and are stopped up. The liquors do not circulate in them with the same degree of quickness, and they are filtered and pumped up but in a very imperfect manner. They stand still and are altered, and this alteration soon communicating itself to the vessels that contain them, circulation ceases, the animal dies, and is reduced to dust.

14. We have carried the parallel between plants and animals from their birth to their death. The parts of which they consist very evidently establish the great analogy there is betwixt these two classes of organized bodies.

But there are other sources of comparisons, we have either avoided to dwell upon, that we might not render our description confused, or have only slightly touched upon; under certain points of view. Such are those presented to us, by *place, number, fecundity, form, structure, circulation of liquors, loco-motive, faculty, feeling, and nutrition.*

We will take a transient survey of these sources, and without endeavouring to exhaust them, content ourselves with barely pointing out their most remarkable and characteristical contents.

Vegetables and animals reside in the same dwelling-place. Being appointed to people and adorn our globe, they are dispersed over its whole surface, and are placed near each other, in order to enable them to afford a reciprocal assistance. Like two great trees growing in the same soil, the animal and vegetable kingdoms entwine their branches together and extend their boughs and roots to the extremity of the world.

The outside and inside of the earth, mountains and vallies, barren and fertile places, countries undiscovered and hid in dark obscurity, the regions of the north and south, rivulets, rivers, ponds, lakes, and seas, have their vegetables and animals.

Many species of plants and animals seem to thrive alike in different climates. Other species are *amphibious,* and live as well out of the water as in it. The *bulrush* and *frog* flourish in meadows, and at the bottom of ponds. Others are *parasites,* and are nourished by the juices they extract from different species. Such are the *misletoe* and the *louse.*

Lastly, Some *parasite* species supply their necessities, in their turn, from other parasites. The *misletoe* has his liverworts, and certain *lice* have their *lice.*

15. There are upwards of twenty thousand species of plants known to us, and new discoveries of them are made every day. A microscopical botany has extended the dominions of the ancient. *Mosses, mushrooms, liverworts,* whose families are innumerable, now take place amongst vegetables, and present the curious with flowers and seeds which before they were unacquainted with. The microscope discovers plants to our view, where we never suspected them. Free-stone is often covered with spots of different colours, commonly brown or blackish. Glass, notwithstanding its fine polish, is not exempt from such spots. We observe *hoariness* on almost all bodies. These spots and this hoariness are found to be gardens, meadows, and forests, in miniature, whose plants that are infinitely small, afford us nevertheless some prospect of their flowers and seeds.

But although vegetables are very numerous in their species, yet they are much less so than animals. Every species of plant has not only its particular species of animals, but there are many species of plants which nourish several species of animals. The oak alone finds nourishment for above 200 species of them. Some attack the *roots* of this tree, which they dig into, and produce therein various *tuberosities*. Others fix themselves in the *trunk*, where they make crooked furrows. Some insinuate themselves into the bark and wood; whilst others penetrate the *interior* parts, whence they extract the juice. Some feed only on the *leaves*. Others *fold* or *roll* them up with a great deal of art. Some form them into *nuts*. Others find both lodging and nourishment in the *fruit*. Nay, gather but a flower by chance either a *daisy*, *poppy*, or *rose*, and you will observe on it a multitude of insects.

In short, where can we turn our eyes without beholding animals? Nature has strewed them every where with a bountiful hand. They were her most excellent productions; she has been liberal of them. She has enclosed animals within animals; she has ordained one animal to be a world for others, which should find therein nourishment in proportion to their wants. The air, vegetable and animal liquors, corrupt matter, dirt, dung, dry wood, shells, and even stones, are all animated, all swarm with inhabitants. What do I say? The sea itself sometimes appears to be one entire collection of animals. The light, which glitteringly reflects on it in the night-time, during hot weather, is produced by an infinite number of very minute glow-worms of a yellowish brown colour, and soft substance, not unlike caterpillars, every part of which, after being divided, and even putrified, shines with the same brightness as when the worm was whole and living. A species of *sea-flies* are also luminous, and communicate their lustre to the waters. There issues from within them a globular matter, which is likewise phosphorous.

Herbs are more numerous in their species and individuals than *shrubs* and *trees*. *Insects* are more numerous, in respect to their species and individuals, than *birds* and *quadrupeds*. There are more *ranunculuses* than *rose-bushes*, and more blades of *grass* than *oaks*.

There are more *butterflies* than *fowls,* and more *vine-fretters* than *dogs.*

16. The magnificence of the creation shines in no part of it with greater lustre, than in the prodigious fecundity of a great number of plants and animals. One single individual may give birth to thousands, or even millions of individuals like itself. Being formed agreeable to those proportions which are only known to that ADORABLE WISDOM that has established them, this great people was at first enclosed within the narrow compass of a rind or ovary. In this dark abode they receive their first life, begin to grow, and are disposed to appear on the vast theatre of the visible world.

If we consider things in a general view, vegetables will be found to be more fruitful than animals. We shall be farther convinced of this, by comparing *trees* with quadrupeds.

Trees produce annually, sometimes for many ages, and their productions are always very numerous. Large *quadrupeds,* as the *elephant,* the *mare,* the *hind,* the *cow,* &c. have seldom more than one at a time, rarely two, and the number they breed is always very moderate. Lesser *quadrupeds,* such as the *dog,* the *hare,* the *cat,* the *rat,* increase in a much greater degree; but their fecundity is but inconsiderable, when compared to that of *ligneous plants.* The elm produces yearly upwards of three hundred thousand seeds; and this astonishing multiplication may continue above a century.

Fishes and *insects* nearly resemble vegetables in fecundity. A *tench* lays about ten thousand eggs: a *carp,* twenty thousand: and a *cod,* a million. An *insect* which produces the *itch,* lays four or five thousand eggs; a female *bee,* forty-five or fifty thousand.

To this amazing fecundity is opposed that of the *wild* *poppy, mustard, fern.* And we must not forget, that most vegetables are propagated different ways; whereas animals are for the most part propagated only by one.

A *tree* may be made to form as many trees as it has branches, boughs, and even leaves. Plants, which are principally designed to supply the necessities of animals, cannot be endued with too great a degree of fecundity.

17. There is hardly any sight more interesting, than that which the infinitely varied forms of plants and animals afford. If one compares the less perfect species with more perfect, or the species of the same class with each other, he is equally struck with the diversity of models, by which *nature* has performed her works in the vegetable and animal kingdoms. He passes with astonishment from the *swinebread* to the *sensitive* plant, from the *mushroom* to the *carnation*, from the *nightshade* to the *oak*, from the *ivy* to the *fir-tree*. He considers with surprise the prodigious multitude of *mushrooms* and *liverworts*, and can never enough admire the fecundity of nature in the production of these plants.

As he goes on to plants that are more elevated in the scale, he stops with pleasure to examine those plants that have *stalks*, from the grass which grows between the stones to that precious plant, whose *ear* furnishes us with the most wholesome food. He considers the various plants that *creep*, from the tender *bind-weed* to the *vine branch* which crowns our hills. He likewise takes a survey of those trees which bear fruit with *stones*, from the wild *plumb-tree* to the *peach*, whose fruit does not excite our admiration more by the softness of its velvet covering and beautiful colour, than by the abundance and exquisite taste of the liquor it yields.

If from the vegetable, he transports himself into the animal kingdom, the prospect becomes still more interesting. He sees opposed to each other in the same portrait, the *polypus* and *sea-dog*, the *day-fly* and *flying-*

fish, the *dancing-bird* and *eagle*, the *grasshopper* and *flying-squirrel*, the *ant* and *stag*, the *cricket* and *rhinoceros*, the *wood louse* and *crocodile*, the *scorpion* and the *ape*.

Another picture presents him with a view of the prodigious number of *butterflies* and *flies*; in considering which, he is astonished at NATURE's complaisance in thus diversifying these little animals, so different from the great ones by their forms, and which have been treated as defective or imperfect beings.

Transferring next his survey to those species of animals immediately higher, he contemplates *shell-fish*, from that whose precious liquor dyes the garments of kings, to the *sailor* that rows with so much grace and skill on the inconstant wave. He observes the different species of fish, from the dangerous *cramp-fish* to the powerful *nerval*, and from the pretty *golden-fish* of China to the *dolphin*, that cleaves the billow with the swiftness of a dart.

He likewise takes a review of those *birds* that live on *herbs* or *seeds*, from the *linnet*, that delights us with his melody, to the *peacock* that pompously displays in our court-yards the gold and azure with which he is enriched. He also observes the birds of prey, from the fierce *merlin* to the *eagle*, whose strength and courage have raised him to the sovereignty over the birds. He next reviews the *quadrupeds*, from the light and timorous *hare* to the *elephant*, whose enormous corpulency attracts every eye; and from the wily *fox* to that noble and generous quadruped which seems formed to have dominion over the animal creation.

Plants, though prodigiously various in their forms, yet are less so than animals. There are fewer gradations from the *truffle* to the *sensitive plant*, or from the *nightshade* to the *oak*, than there are from the *oyster* to the *ostrich,* or from the *sea-nettle* to the *ouran-outang.* Plants, being essentially more simple than animals, have not given birth to so many combinations.

The forms of animals afford us a singularity which is extremely remarkable, and sufficient to distinguish them from vegetables; I mean, those admirable metamorphoses which the same insects exhibit to us, which are sometimes so opposite, that it does not appear to be the same animal.

But may we not compare the bud in which a plant or flower is infolded, to the covering of a *chrysalis* which conceals the *butterfly* from our sight? And as the plant cannot produce seeds till the flower has issued from the bud, so neither can the butterfly propagate till it has cast off the sheath of the *chrysalis.*

18. It is not so easy to compare plants and animals in their *interior forms* or *structure,* as it is in their *exterior.* We may judge of the one by a single glance of the eye: we must bestow a particular attention, to judge of the other. We penetrate with greater difficulty, into the inside of a plant, than into that of an animal. The microscope, scalpel, and injections, which are so serviceable to us in the anatomy of animals, assist us very imperfectly in that of plants. It is likewise true, that this part of organical economy has been less studied.

But how imperfect soever the anatomy of plants may be, we are able to discover some of their principal vessels. These may be ranged under two general classes; the *longitudinal* that extend the whole length of the plant, and the *transverse* vessels, or such as are placed across it. The *sappy* vessels and *trachæan* belong to the first class; the *utriculi,* or *insertions,* to the second. The vessels containing the sap seem designed to convey the juice. The *utriculi,* or little bags, appear intended for digesting it.

Some plants seem to be entirely composed of *utri-*

culi: such are certain species of *roots* and *sea-plants*, whose texture is almost together vesicular. It is the same with those animals which seem to consist of stomach only, as the *polypus* and *tape-worm*.

One of the principal characters by which we may distinguish insects from large animals, is, that the former have no bone within them. What they have of a bony or scaly nature is placed on their outside for a support or defence to the more delicate parts underneath, or to sustain the body with greater advantage. Thus we see that in almost all insects, *properly so called*, the head, corslet, legs, rings, &c. are either wholly, or for the most part doubly covered with scales.

Herbs differ from *trees* as insects from large animals. They have no *ligneous body* in their centre. What they have of a ligneous nature, appears on the outside, and serves to protect the weaker parts of the plant. Thus we find plants with tubes are strengthened by knots placed at regular distances; so that the lowermost knots which are designed for the base, are stronger and nearer each other than the upper ones. It is on the same account that the roots of many herbaceous plants, as well as the *calixes* of flowers, and the capsules or coverings of the seeds, are made almost ligneous.

Herbs grow and become hard sooner than *trees*. *Insects* than great animals. Herbs and insects, being of a softer consistence than trees and large animals, extend themselves with greater ease, and sooner arrive at the peiod of their extension. Besides, the concentric beds of the bark of trees, and those of the *periosteum* of animals, being far more numerous than the relative beds of herbs and insects, must needs require a longer time for their growth.

We may distinguish two kinds of parts in organized bodies; to wit, *similar* and *dissimilar*. The former are composed of fibres of the same kind; the latter, of fibres of various sorts. The nerves, arteries, veins, lymphatic vessels are the *similar* parts of our bodies; the brain, heart, lungs, stomach, the *dissimilar.* Plants are almost entirely composed of *similar* parts. The vessels containing the sap, the *trachæa,* and *utriculi,* are of this kind. These different vessels are pretty uniformly dispersed throughout the whole body of the plant: they enter into the composition of all its parts. They are to be met with in the root, stalk, branches, leaves, flowers and fruits. The least fragment, the smallest leaf, is a representation of the whole, an abridgement of the plant.

There are likewise animals which are nearly composed of *similar* parts. Of this number are many species of long worms, and some *acquatic millepedes, nettles,* and *sea-stars, polypuses, moths, earth-worms.* All these animals are formed in such a manner, that each part of them, even the smallest, corresponds in miniature to the whole in all parts.

In the *long worms* I just mentioned, we observe very distinctly a stomach, a heart, and some very small vessels which seem dependent on the latter. There is likewise no room to doubt that there is beneath the stomach, a *medullary* string, like that observed in other species of worms and caterpillars. Their *viscera* are not distributed into certain regions of the body; they are universally dispersed throughout its whole length; so that we may truly affirm that these insects are all brain, all stomach, all heart. But this brain, stomach, and heart, appear extremely simple: the first is scarce any thing more than a nervous piece of net-work, the second a membraneous bag, and the third a grand artery.

Polypuses, which are more simple in their structure, are only a kind of bowel, sown with an infinite number of small seeds, which are tinged with the colour of the aliment.

Tape-worms partake of the structure of polypuses, but seem to be more compounded. They are formed of a chain of flat, membraneous, and whitish rings, jointed together like the divisions of a reed. Each ring has on its upper part, or on one of its sides, a more or less sensible eminence, in the centre of which is a small round aperture. The middle of the ring is full of vessels of a purple or whitish colour, which perform a labour that attracts the attention of the observer. The rest of the ring is filled with an infinite number of small white seeds. Such is essentially the structure of the tape-worm in its whole extent; there is no perfect variety or resemblance between all the rings, the assemblage of which composes a kind of ribband or lace, which extends sometimes several hundred feet in length.

Earth-worms are, of all the insects I have mentioned, those whose inside seems to be the most compounded, chiefly because in them the two sexes are united: but the most essential organs of life are distributed in them likewise through the whole length of the animal.

Organized bodies, whose structure is so simple and uniform, that each part of them has in a small compass an organization resembling that of the whole in a greater extent, enjoy divers prerogatives that have been denied to organized bodies of a more complicated structure. The first of these are not destroyed when divided asunder. Their different portions continue to live, and the wounds which have been given to them easily consolidate. These parts vegetate, receive nourishment, produce new organs, and multiply. Such wonders as these the vegetables and insects we have lately treated of exhibit every day: wonders which we have not sufficiently admired in the former, and which perhaps we too much admire in the latter.

Large animals do not furnish us with the same *phenomena.* The consolidation of their wounds, and the reunion of their fractures, although oftentimes attended with circumstances which render them very remarkable, strike us but slightly when compared with what we observe analogous in polypuses, and other insects that multiply by slips. The motions we perceive in certain parts of great animals, when separated from the body, or after the death of the animal, affect us only with a slender degree of surprise, when we consider the motions of different parts of worms, or those of some *millepedes*.

But may there not be some misconception in these different judgments? We judge of the effect produced, as considered in itself, and separate from the circumstances accompanying it; whereas we should judge of it with relation to the greater or less degree of composition whereof the body, in which this effect is produced, consists. There is as much, and indeed more to be admired in the consolidation of certain wounds, or in the reunion of certain fractures of our body, than there is in the consolidation of the wounds of polypuses, or in the reunion of parts which have been separated from them. A very simple machine is easily repaired; a machine that is extremely compounded, cannot be repaired with the same facility. When we reflect on the prodigious number of similar and dissimilar parts contained in the composition of the bodies of great animals, and particularly in that of the human body; when we attend to the strict connexion of all these parts, and to the degrees of composition in each of them, we cannot sufficiently wonder that the various accidents which happen to these bodies are not attended with greater consequences; we shall at the same time perceive the reason why they are not enabled to propagate like bodies whose organization is more simple.

But independently of the greater or less degree of the composition of parts necessary to life, as soon as these parts are found placed in different regions of a body, and are not dispersed throughout its whole length, such a body cannot be multiplied by slips. The AUTHOR OF NATURE, by denying, in his wisdom, this property to large animals, by confining the sources of life in them within a narrow circle, has secured them from harm by many advantages. Compare the result of the motions or actions of a sea-worm with that of the motions or actions of an ape, and you will soon perceive which of these animals has been most favoured.

Finally, organized bodies, to which a power has been granted of multiplying by a method which seems to tend to their destruction, are such as are exposed to the greatest dangers, and whose life is necessarily threatened every moment with a thousand various accidents.

19. Amongst the motions we observe in the animal machines, that of the circulation holds the first rank, either by its importance, or its nature, duration, and the number of organs by means whereof it is performed. There is in this motion an air of grandeur that seizes forcibly on the mind, and which, by making it sensible of the narrow limits of human understanding, penetrates it with the most profound respect, and fills it with the highest admiration of the INFINITE MIND which illustriously shines in the DIVINE AUTHOR of it.

In the centre of the breast, between two spongy masses known by the name of lungs, is deposited a fleshy pyramid, whose base bears two small funnels like ear-rings, which communicate with two cavities contained in the inside of the pyramid, and which divide it according to its length into two chambers or *ventricles*, the *right* ventricle and the *left*. This pyramid is the *heart*, the main spring of the machine. It has two principal orders of *muscular fibres*; some of which pass obliquely from the base to the point, others cut the latter transversely. From the exercise of these fibres two opposite motions result; one of *dilatation*, the other of *contraction*. The heart seems to execute these motions by turning on itself like a screw. Its point moves towards or from the base, by rising or falling obliquely.

Two great vessels, viz. an artery and a vein, communicate with each ventricle. The artery,* which communicates with the right ventricle, conveys the blood to the lungs. The vein,† which communicates with the same ventricle, forms the principal trunk of the veins, and carries back the blood from all parts to the heart. The artery,‡ which goes into the left ventricle, is the chief trunk of the arteries, and that which conveys the blood to all parts. The vein,‖ which ends at the same ventricle, transmits to it the blood that has been conveyed from the lungs.

The principle trunks of veins and arteries, are divided into several branches at a small distance from the heart. Some tend towards the upper extremities, others towards the inferior.

The arteries and veins decrease in diameter, and are ramified more or less according to their distance from their origin. There is no part to which these do not distribute one or more ramifications.

When they have arrived at the most remote parts, the arteries have an intercourse with the veins.

The arteries are composed of several membranes, placed on each other. The veins have similar membranes, but more slender, and weaker. The veins were not designed to exercise the same power as the arteries. These latter must necessarily, like the heart, and for the same end, dilate and contract themselves: they have therefore been provided with a very elastic membrane. The exercise of the veins should not be violent.

At the root of the arteries, and in the inner part of the veins, are placed little sluices or valves, which by sinking and rising again open and shut the canal. These valves are deposited in the veins, in a contrary sense from that for which they are in the arteries. We shall presently account for the cause of this difference.

20. After having been masticated and dissolved in the

* The pulmonary artery. † The vena cava. ‡ The grand artery, or the aorta, ‖ The pulmonary vein.

mouth and stomach, the aliment descends into the intestines, where it receives a new preparation by the mixture of two liquors, one of which is furnished by the liver, and is called the bile; and the other by a species of * gland situated under the stomach.

The aliment is thus converted into a kind of greyish pulp, which has received the name of *chyle.* Being shifted from place to place by the vermicular or *peristaltic* motion of the intestines, and strongly pressed against their sides at the instant of their contraction, the chyle penetrates into extreme small vessels,† which open themselves in the internal membrane of the intestinal canal. These vessels transmit the chyle to very small glands which are covered with a kind of membrane ‡ situated in the midst of the intestines, and round which they are in a manner rolled. After being filtrated in these glands, the chyle is received by other vessels, ‖ which convey it into a concavity § placed along the spine, and which pours it into a vein situated under the left clevicle. There it enters into the blood, and loses the name of *chyle.* From this vein the new blood passes into the upper branch of the principal trunk of veins, which carries it towards the heart. It passes into the right lobe, which opens at its approach, and by closing immediately, forces it into the right ventricle which is dilated in order to receive it. The heart instantly contracts itself; the valves with which the ventricle is furnished, raising themselves to oppose the reflux of the blood into the lobe, it is compelled to pâss the artery, which is appointed to carry it to the lungs. The valves, which are placed at the entrance of this artery, sink down; the artery dilates, and the blood advances into the cavity. The valves rise again, and prevent its return towards the heart. The artery contracting itself, the blood is impelled farther, and by these alternate di-

* The pancreas and pancreatic juice. † The primary lacteal veins.
‡ The mesentery and mesenteric glands.
‖ The secondary lacteal veins. § The thoracic duct.

latations and contractions of the vessel, it is conveyed to the lungs, where it runs through every part of them. The ramifications of the *trachæ*,* which are dispersed in the *viscera*, carry thither a fresh and elastic air, which, by acting on the lungs, dilates, winds them about, extends and opens them, and by that means facilitates the course of the blood into the smallest ramifications of the artery. Besides, being impregnated with this air, the blood becomes thereby attenuated, is cooled, and receives a more lively colour. After its arrival at the extremities of the artery, it passes into that of the *pulmonary* vein, which conducts it to the left ventricle of the heart. This latter, by contracting itself, pushes it into the *aorta*,† which by continually dividing and subdividing itself, distributes this balsamic liquor to all the parts, in order to promote their growth, or support, and occasion different *secretions*.

21. Such is the admirable mechanism of the circulation of the blood in men, and in those animals which we are best acquainted with. But how greatly does this imperfect sketch fall short of the reality! How incapable are these outlines of expressing the beauties of this noble subject! And who can account for the manner by which the strength of life is repaired and recruited? Who can conceive the cause of that perpetual motion of the heart, which continues without intermission for the space of seventy, eighty, or a hundred years, which has lasted for ages in the first race of men, and which remains almost as long in some species of animals? Have we discovered the exact part where the artery is changed into a vein? Have we disclosed the mystery of the secretion of those spirits, whose prodigious subtilty and activity give them a near resemblance to light? Can we even determine in what manner the grosser secretions are performed? Do we understand the true mechanism

* The bronchia. † The principal trunk of arteries.

of muscular motion? Have we been able to find out the source of that great strength which often so far exceeds that of the heart? All these dependencies on circulation are yet unrevealed to us. The gloom of night still wraps these regions in dark obscurity, and you are earnestly desirous of chasing it away from before that sun which alone can dispel these shades. Will the dawn of that day ere long gild the horizon of the learned world? Or is the time of its breaking forth upon us yet afar off?

But if we are not able to discover the whole, we may at least see enough of it to excite our admiration; and the sketch which I have just drawn of the circulation, is sufficient to enable us to conceive the highest ideas of the SOVEREIGN MIND, which has appointed the manner, duration, and end of it.

Far less magnificent in its plans, less skilful in the execution of them, hydraulics offer to us but faint images of this miracle, in those machines by means of which water is raised above the mountains, in order to its being distributed into every quarter of a great city, and made to circulate and issue forth, under a hundred various forms, into those gardens which art and nature vie with each other in adorning and embellishing.

The works of the CREATOR must be compared with the works of the CREATOR. Ever like HIMSELF, HE has impressed on all HIS productions a character of nobleness and excellence, which demonstrates the grandeur of their origin. From that immense mass of water which encompasses the great continents, there incessantly arises an ocean of vapours, which, being rarefied by the combined action of the sun and air, spread themselves in the upper region of the atmosphere, where they remain suspended *in equilibrio*, being intermixed with the fluid in which they float, and gravitate with it. Collected afterwards into clouds more or less dense, and borne on the wings of the winds, they fly across the celestial plains, which they adorn with their rich colours, and continually variegated forms. Fixed at length on the mountain tops, they pour upon them abundant rains, which being collected in the vast reservoirs, embosomed within them, furnish, by a happy circulation, a supply to fountains, rivers, lakes and seas. Like veins and arteries, the rivers flow meandering, and branching on the surface of the earth, they run through immense countries; water, fertilize, and unite them by a reciprocal commerce, and majestically rolling their waves toward the sea, plunge themselves into it, in order to be again exhaled in vapours, and re-enter afresh into the channels of this magnificent circulation.

22. Does the sap *circulate* in plants as the blood circulates in animals? Is this new mark of analogy between these two classes of organized bodies as real as it has appeared to be? Small bladders full of air which have been thought to be discovered within the leaves, have convinced us that they were the *lungs* of the plant.

But there have not been discovered in plants vessels analogous to veins and arteries. No organ has been seen in them capable of performing the functions of the heart. A tree which is planted a contrary way, with the roots a top and the branches in the ground, lives, grows, bears fruit; from its roots, branches shoot forth; from its branches, roots. The same is observed with respect to slips and layers. A young branch, or young fruit, after being grafted on a subject foreign to itself, incorporates with it, and derives from thence the same degree of growth it would have received from the plant whence it was detached. Experiments demonstrate, that the motion of the sap depends entirely on the alternatives of heat and cold, and the vicissitudes of day and night. It is evident that the sap rises in the day from the roots to the leaves, and falls in the night from the leaves to the roots. In a word, the course of the sap nearly resembles that of the liquor contained in the tube of a thermometer. All is reduced to a simple counterpoise.

23. The nourishment of the more perfect animals requires to be more wrought than that of plants. Hence the necessity of the *circulation of the blood.* The preparations of the sap do not require such a punctual, regular, and constant motion; bare poisings suffice. Large animals eat but at particular times: a pressing sensation which induces them to take nourishment, does not continually act upon them. The different preparations their aliment should undergo, would be disturbed or interrupted, were a fresh supply to be received within them before the former was sufficiently digested.

Plants, on the contrary, are in a state of perpetual suction; they draw in nourishment continually, and in a very great quantity, in the day-time by their roots, in the night by their leaves. There is a plant which receives and transpires, in the space of twenty-four hours, twenty times more than a man.

But if plants differ so much from large animals by circulation, on the other hand some species of animals seem nearly to resemble plants by their want of this circulation. Not the least appearance of this motion is to be perceived in the *polypus,* the *tape-worm,* the *pond-muscle,* and divers other shell-fish.

24. One of the ancients defined a plant to be a rooted animal. He would undoubtedly have defined an animal to have been a wandering plant. The loco-motive faculty is one of those characters which present themselves first, when we compare the vegetable kingdom with the animal. We see plants that are constantly fixed on the earth. Being incapable of seeking their nourishment, it is ordained that this nourishment shall seek them. The greatest part of animals on the contrary, are subjected to the care of providing their own subsistence. *Nature* has not always deposited near them such nourishment as was necessary for their sup-

port. *She* has thought proper to oblige them to procure it for themselves, often with much labour. And the different methods by which she has instructed each species to obtain this end, much diversify the scene of our world.

Whilst the ploughman opens the earth, to entrust with it the seeds necessary to support him, the mole and the mole cricket are clearing for themselves different routs, in the same, to search for the food allotted to them. The huntsman pursues his prey with an obstinate resolution: triumphing in his swiftness and strength. At other times preferring craft he becomes master of it by laying snares for it. The tyger rushes on the fawn sporting in the meadow. The cat watches motionless and silent, till the young mouse issues forth from its retreat, that she may dart upon it in a moment. Some species of animals, resembling mankind by their prudence, lay up provisions against a time of scarcity; build themselves magazines, in which are observed such just proportions, as to give us cause to doubt whether it was the workmanship of a brute, were we not convinced that this brute itself is the work of SOVEREIGN REASON.

25. How great is the distance in this respect from the beaver and bee, to the gall or cochineal insect, the oyster, the sea nettle, and several other kinds of insects and shell-fish? The gall insect,* being confounded, by his immobility and form, with the tree on which he lives, contents himself with extracting its juice. Carried by the wave to the sea-shore, the oyster remains fixed there, and all its motions consist in opening and closing its shell. The sea-nettle, and all the different polypuses with *pipes*, being continually fixed to the same place, open and shut like a flower; extend and contract themselves like a sensitive plant; stretch out arms, by means of which they seize insects. This is their principal

* See chap. viii.

character, and the least equivocal character of their *animality*.

Thus it appears that the *loco-motive* faculty is not more proper for distinguishing the vegetable from the animal, than those other characters which we have before treated of. In the mean time, what can be more distinct in appearance than a plant is from an animal? Or what more easy to characterise in the sight of the major part of mankind? But when once we are convinced that every thing in nature is shadowed over, we are not surprised at the difficulties we meet with in our attempts to distinguish beings. We expect to see the species enter again into each other; and confine ourselves to the smallest latitude, or to that which is attended with the least uncertainty. In this principle we will conclude the parallel: let us see whether feeling, and the manner by which animals and vegetables are nourished, will furnish us with any thing more characteristical.

26. If there be any faculty which seems peculiar to the animal, it is certainly that of *feeling*. Being united to an organized substance by ties which perhaps are known to GOD only, this soul composes with this substance a *mixed* being, a being which partakes of the nature of bodies, and of that of spirits. As a portion of matter, it is a machine which is admirable in its structure, and on which corporeal objects act mechanically. As a spiritual substance, it is affected at the presence of spiritual objects in a manner which does not seem to have any relation with that by which material substances act on each other. From the expression of external objects on the machine, there results a certain motion in the machine From this motion there follows a certain sensation in the soul, which is succeeded by the reaction of the spiritual substance on the corporeal; a reaction which manifests feeling from without, and which is the expression or *sign* of it.

The various sensations in the animal may be reduced to these two general classes, *pleasure* and *pain*, separated from each other by degrees which are frequently insensible, and issuing from the same origin. The expression of pleasure and pain is not alike in all animals; because the organs, by means whereof the soul manifests her sentiments, are not the same in all.

There are species in which feeling is manifested by a greater number of signs, more varied, more expressive. What expression, for instance, is there in the air, the motions, and the various attitudes of an ape, a horse, a dog, a cat? There is not much less expression in birds than in quadrupeds. Fishes do not express themselves with the same clearness and energy; they form a dumb people, amongst whom the language by signs is little practised: but the extreme vivacity of their motions seems, in part, to compensate for their sterility of expression. Reptiles, shell-fish, and insects, which are still at a greater distance from us than fishes, express to us their feelings in a more obscure manner; but which, notwithstanding, we can conceive to a certain degree, and often acknowledge to be very expressive.

On the contrary, we do not discover in the plant any sign of feeling. All in that seems to be purely mechanical: its life appears to be less a life than a simple duration. We cultivate a plant, or we destroy it, without experiencing any thing similar to what we meet with when we cherish an animal, or put it to death. We see the plant shoot forth, grow, flourish, and bud, as we perceive the hand of a clock to have passed over the points of the dial.

These considerations lead us to consider *feeling* as a character proper for distinguishing the vegetable from the animal.

27. Since, then, the faculty of feeling furnishes us but with a doubtful character for distinguishing the vegetable from the animal, which is that we should have recourse to with this view? I think we have exhausted

them all: we have at least treated of them all in a cursory manner. But we have not examined them all under their various aspects. There is one of them, which being considered in a certain point of view, may, perhaps, procure us what we have in vain searched for in the others.

We may now consider the position of those organs by which plants and animals receive their nourishment. These organs in plants are the roots and leaves: both of them are furnished with pores, by means of which they pump in the nutritious juice. These pores terminate at small vessels, which transmit the juice into the inner part; or, rather, these pores are only the extremity of these vessels.

Animals have organs which are entirely analogous to roots and leaves; I mean *lacteal veins*, or vessels which answer the same purpose: these veins open themselves in the intestines, and pump the chyle into them, which they convey into the channel of circulation. An animal is then an organized body, which is nourished by roots placed *within him*: a plant is an organized body, which receives its nourishment by means of roots placed *on its outside.*

Yet an animal which is nourished by pores distributed on its outside, renders this character ambiguous. The *tape-worm* seems such an animal. It forms in the intestines a great number of plaits; and sometimes entirely fills the capacity of this canal. Each of the rings that compose it, and whose length is rarely more than one or two lines, is pierced with a small round aperture, by which one may see the chyle issue, which the worm is full of, and which constitutes its principal nourishment: if this aperture is a kind of sucker, by the help of which the insect pumps the chyle that surrounds it, this method of nourishing itself varies but little from that of plants.

But, without seeking very far for examples of animals that are nourished like plants, this is the case of all animals, whether oviparous or viviparous, whilst they are inclosed in the egg, or in the belly of their mother: the *umbilical* vessels may be considered in the *egg*, or in the matrix, as roots which imbibe the nourishment. It is the same with respect to insects that multiply *by shoots*: whilst the young one still adheres to its mother, it is nourished in a manner little different from that which is peculiar to branches. Animal grafts nearly resemble vegetable in this particular.

Lastly: The skin of the human body imbibes, like the leaves of plants, the vapours with which the air abounds; and although men draw in much less nourishment by this means than vegetables, it is, nevertheless, true, that their skin and leaves have, in regard to this circumstance, a great affinity to each other. Perhaps we may be able, some time or other, to discover animals which are nourished by their skin only, as certain plants are by their leaves.

28. Do we then in vain seek for a peculiar character whereby we may distinguish the vegetable from the animal? I perceive a new property, which will, perhaps, furnish us with what we seek for.

A *muscular* fibre contracts of itself on the touch of all bodies, whether solid or liquid: this property is known by the name of *irritability*. It has nothing in it common to sensibility: the parts which are most sensible are not *irritable*, and the parts which are most irritable are not *sensible*. Neither ought we to confound irritability with *elasticity*: a dry fibre is very elastic, and not at all irritable. Animals purely gelatinous are not elastic, and are, notwithstanding, very irritable. In short, the fibres of old men, though much more elastic than those of infants, are much less irritable.

We have seen that the heart is a real *muscle*. If we extract it from the breast, it will continue to move till it has lost its natural heat. The heart of a viper, or tortoise, beats strongly for the space of twenty or thirty hours after the death of the animal. Water, or air, when introduced into the *ventricle*, are sufficient to restore to the heart the motion it has lost.

The *peristaltic* motion of the intestines is likewise owing to their irritability. But the following is what we should not have guessed at. If they are plucked hastily from the lower belly, and cut into pieces, all these pieces will crawl like worms, and contract themselves on the slightest touch.

So that not only every muscle, but also every fragment of a muscle, and even every muscular fibre, contract themselves more or less on being touched by any body whatsoever, especially if that body be of a stimulating nature; and as the fibre contracts, so it likewise recovers of itself, and this alternate exercise lasts for a time proportionable to the degree of irritability.

It is evident, from all the experiments, that the *vital* parts are the most irritable. The heart is the most irritable of all, and next to that, the intestines and diaphragm.

The nature of irritability is unknown: we only judge of it by its effects. It probably resides in the elastic fluid which is interspersed between the *lamellæ* of the fibre. The *nerves* are not irritable; but if a nerve be pricked, the muscle at which it terminates will contract itself. The nerves may then give motion to the muscles; but they do not communicate an irritability to them which they are not possessed of themselves, they only put it into action; and thus they are the ministers of the affections of the soul.

Irritability then seems to be what constitutes the *vital power* in the animal; and this property has not been perceived in the vegetable. Is it not then the *distinguishing* character we seek for?

CHAP. XI.

Of the Industry of Animals.

1. HITHERTO we have scarcely considered animals in any other light than with respect to the organization, and the immediate and general consequences of it. We will now contemplate their industry, which is still more interesting to us.

Some animals seem reducible to feeling only: others have all our senses, and rise almost to understanding. The distance from the *polypus* to the *ape* appears enormous.

Imagination and memory are observable in divers species: imagination, in their dreams; memory, in the recollection of such things as have affected them. Places, persons, animate and inanimate objects, are traced out in their brain, and they act agreeably to these representations.

The degree of knowledge in each species answers to the place it occupies in the general plan. The sphere of this knowledge extends to all cases which the animal may naturally meet; and if the animal happens to be drawn from his natural circle, and nevertheless is not entirely removed out of it, we may conclude that this new situation has a relation to one of the cases to which the sphere of his knowledge extends.

The way whereby animals vary their proceedings as necessity requires, furnishes one of the strongest arguments against the opinion which transforms them into mere machines. The philosopher who attributes to them a soul, founds his judgment on the analogy of their organs with ours, and of their actions with several of ours: those who make the soul material, forget that even feeling is incompatible with the properties of matter.

The greater the number of cases is to which the knowledge of an animal extends, the higher is this animal elevated in the scale.

The preservation of life, the propagation of the species, and the care of their young, are the three principal branches of the knowledge of animals; but all are not alike to be admired in these respects.

The *oyster* knows only how to open and close its shell.

The *spider* spreads a net for his prey; waits, like a huntsman, till some insect falls into the snare; hardly has he touched it, before he darts upon it. Is he armed, or too nimble? He fastens the lines to him with wonderful skill, and thus disables it either from flying or defending itself.

Divers species of animals live from day to day, without taking any thought for the succeeding day; others seem endued with a kind of foresight, construct magazines with abundance of art, which they fill with various kinds of provisions: such are the *bee* and the *beaver*.

Among animals that live by prey, some, like the *eagle* and the *lion*, attack with open force; others, as the *hawk* and the *fox*, join craft to strength. Some save their lives by flight; others, by hiding themselves under the earth or water; while others still have recourse to divers stratagems to facilitate their flight, and evade the pursuit of their enemy.

Those philosophers, who take a great deal of pains to define *instinct,* are not aware, that in order to do it, they should spend some time in the head of an animal, without becoming the animal itself. To say in general, that instinct is the result of the impression of certain objects on the machine, of the machine on the soul, and of the soul on the machine, is to substitute terms that are a little less obscure, instead of a very obscure term; but the idea does not issue from the thick darkness that covers it: we well know what is not instinct, but are utterly ignorant what it is. It is not understanding, or reason: the brute has neither our notions, nor our *mean* ideas, because it has not our *signs.*

2. At the same time that NATURE has taught divers animals the method of attacking and pursuing their prey, she has instructed them in that of self-defence or escaping. If we were conversant in the books of nature, we should there see, without doubt, that the profit always makes amends for the loss. A register of the births and deaths of some species puts this truth beyond all controversy.

Those species which multiply most, have the greatest number of enemies. *Caterpillars* and *vine-fretters* are attacked as much within as without, by I know not how many insects, that are always bent on destroying the individuals, without being able to effect the destruction of the species. Many species seek their living or retreat in the inner part of the earth, or in that of plants and animals. Others build themselves nests or shells with amazing art, where they pass their time in weakness and inactivity.

Some that are more skilful, can, like us, make themselves clothes, and even procure matter for their nourishment. They strip our cloths and furs of their hairs, and make a kind of stuff of it, wherewith they clothe themselves. The form of their dress is very simple, but very commodious. It is a sort of muff or case, which they can lengthen or widen as they find occasion. They lengthen it by adding to each end new layers of silk and hair, and widen it as we do a glove, by cutting it in the middle according to the length of it, and by engrafting a piece. You may imagine that I am speaking of *house-moths*: *field-moths*, which clothe themselves with leaves, surpass them in industry.

Several kinds of *fishes* and *birds* change, at a stated time, their dwelling-places. We have seen numerous shoals of *herrings* and *cod-fish*, and *flocks* of *geese, quails,* and *crows,* resembling thick clouds that sometimes darken the air. By such periodical emigrations the species are preserved, and in their long pilgrimages nature is their pilot and provider.

3. The *grasshopper, lizard, tortoise,* and *crocodile,* furnish examples of animals that scarce take any care of their eggs, and are almost wholly unmindful of the young that are hatched from them. They lay them in the earth or sand, and leave the sun to communicate the warmth necessary for them. Shell-fish practise the same method: some spawn in the water; others between stones, or in the sand.

The instinct of the different species consists in depositing them in places where the young may find proper nourishment at their birth. The mothers commit no mistake with respect to that. The *butterfly* of the *cabbage-caterpillar* never lays her eggs on meat, nor the *flesh-fly* on the cabbage.

The gnat, that flutters in the air, was at first an inhabitant of the water. For this reason her eggs are always deposited in the water. The mass formed by them resembles a little vessel which the insect sets afloat. Each egg is in the form of a keel. All the keels are vertical, and are disposed back to back. The gnat lays but one egg at a time. We cannot devise how she can cause the first egg or keel to remain in the water

Her method is nevertheless very simple, but much more ingenious. She stretches out her long legs behind her, crosses them, and by thus forming an angle of them, receives the first egg, and holds it at pleasure. A second egg is soon placed next the first; then a third, fourth, &c. The base of the pyramid thus widens by little and little, and at length is capable of sustaining itself.

Some species glue their eggs with great symmetry and propriety round the branches or small shoots of trees, like rings or circles. One would be apt to say, that some skilful hand had been diverting itself in fitting pearl bracelets on the sprigs. A caterpillar, which, from the distribution of its colours, is called *livery*, transforms itself into a butterfly, that disposes her eggs in this manner, and forms these pretty bracelets of them.

Other butterflies do still more: they strip themselves of their hair, and make with it a kind of nest for their eggs, where they lie soft and warm. Such in particular is the industrious workmanship of the butterfly, proceeding from that called the *common* caterpillar, because it is in fact most common in these countries.

4. Certain species are so attached to their eggs, that they carry them about with them every where. The *wolf* spider encloses her's in a little silk purse, which she bears on her hind-part. Does any one destroy it, or take it from her? Her natural vivacity and agility abandon her: she seems to fall into a kind of languor. Has she the happiness to recover the precious trust? She instantly seizes it, carries it away, and betakes herself to flight. As soon as the little spiders are hatched, they collect and arrange themselves skilfully on the back of their dam, who continues for some time to bestow her attention on them, and to transport them with her wherever she goes.

Another spider lodges her eggs in a little silk purse, which she wraps up in a leaf. She fixes herself on this purse, and sits on her eggs with amazing assiduity. Another, to conclude, encloses her's in two or three little silk balls, which she suspends by threads; but has the precaution to hang before, at a small distance, a little bunch of dry leaves, to conceal them from the inspection of the curious.

5. Divers species of *solitary* flies are not less to be admired, as well for their foresight in amassing provisions for their little ones, as for the art displayed by them in them the nests they prepare for their reception. The *mason* bee, so called because like us, she understands the art of building, performs such works in masonry, as one would imagine must greatly surpass the strength of a fly. With sand, collected grain by grain, and glued together with a kind of cement much preferable to ours, she erects a house for her family: a very simple one indeed, but extremely solid and commodious. It is divided within into several chambers or cabins, on the back of each other, without any communication between them. One general foldage, a wall of enclosure comprehends them all, and leaves no opening without. This wall must be broke before the apartments can be seen, and it is found to be as hard as a stone. These nests are very common on the fronts of houses: they there resemble little oval hillocks, of a different grey from that of the stone. The fly that is the architect of these buildings deposits an egg in each chamber, and shuts up in it at the same a stock of wax or *paste*, which is the nourishment appropriated to her young.

Another fly, which may be called the *carpenter* * bee, because she works in wood, likewise builds apartments for her family, but in a different taste from that of the *mason*. Sometimes she distributes them into stages; sometimes disposes them in a row. Cielings or partitions, artfully made, separate all these stages or cham-

* The *wood-piercing* bee.

bers, and there is an egg deposited in each of them, with the quantity of paste necessary for the young.

6. These various kinds of work require in general less skill and genius than labour and patience. There is a very different degree of art and sagacity displayed in the nest constructed by another fly with single pieces of leaves only. This nest is a real prodigy of industry. When it is taken to pieces, and narrowly examined in all its parts, one cannot conceive how a fly should be able to cut them out, turn, and put them together with so much propriety and exactness. When viewed on the outside, this nest very much resembles a tooth-pick case. The inside is divided into several little cells, in the form of a thimble, set in one another as thimbles are in a tradesman's shop. Every thimble consists of several pieces, which are separately cut from one leaf, and whose form, circumference, and proportions tally with the place each is intended to occupy. The same method is used with respect to the pieces that form the case or common cover. In a word, there is so much exactness, symmetry, uniformity, and skill in this little master-piece, that we should not believe it to be the work of a fly, did we not know at what school she learnt the art of constructing it. We may naturally conjecture that each thimble is a lodging for a little one; but we could not have imagined that the paste which the mother provides for it is almost liquid, and that the little cell, which is entirely composed of small pieces of leaves, is notwithstanding a vessel so well closed up, that this paste never spills, even when the vessel is stooped.

Many brutes act in concert with each other. A drove of oxen is grazing in a meadow: a wolf appears: they immediately form into a battalion, and present their horns to the enemy. This warlike disposition disconcerts him, and obliges him to retire.

In winter, hinds and young stags assemble in *herds*, in the more numerous companies as the season happens to prove severe. They warm each other with their breath.

In the spring they separate, the hinds concealing themselves in order to bring forth. The young harts remain together, love to walk in company, and are only parted by necessity.

Sheep that are exposed to the sultry heat of the dog-days in an open plain, keep near each other, so that their heads touch; they hold them inclined towards the earth, and snuff up the fresh air which comes from beneath them.

Wild ducks, that are accustomed to change their climate, range themselves in their flight in the form of a wedge, or an inverted V, that they may cleave the air with the greater ease. The duck at the extreme point leads the flight, and cleaves the air first of all. After a certain time he is relieved by another, the second in his turn by a third, &c. In this manner each bears a share in the laborious part of this office.

8. Animals to whom the company of their own kind is useful, have been rendered fit for this commerce. And if the AUTHOR of nature had man in view with respect to this particular, as we may without pride suppose, the means will be found to correspond perfectly well with the end. In effect, how many embarrassments and inconveniencies would have accompanied the divers services we deduced from domestic animals, if individuals of the same species had not power to cohabit together!

The spirit of society is not altogether limited to individuals of the same species, but extends likewise in a certain degree to those of different species, and from thence man also derives some advantage. The custom of seeing each other, of eating their meals in common, of reposing under the same roof, confirms the natural disposition of domestic animals to live in society. The connections which result from it become so much the stronger as they begin earlier or nearer to their birth.

Thus animals that are not appointed to live together, may notwithstanding form a sort of society: the natural inclination each of them has to live with those of a like kind, is susceptible of modification or extension.

Every individual knows his like; those of the same society likewise know them. It is observable, that if strange fowls are brought into a poultry-yard, those of the place will persecute them, till cohabitation has made them members of the society.

The outside of the body exhibits divers characters, by means of which individuals of the same society may know each other, and distinguish strange individuals. But among these physical characters there may be some *mixed* ones, or such as belong as much to the soul as the body, which the animals of the class we are treating of, are capable of seizing; such are the air, posture, gait. The individuals of that species, which are not yet become familiar in their new habitation, seem fearful or embarrassed: this fear or embarrassment detects them, and excites or encourages others to attack them.

That kind of society in which domestic animals live, gives room for a remarkable observation; the young lamb distinguishes her mother from amongst 3 or 400 sheep, although there does not appear to be any sensible difference betwixt them.

9. Nothing is more wonderful than those legions of flying creatures, that at a stipulated time pass from one to other very remote countries. What instinct assembles them? What compass directs them? What chart points out their way? We presently conceive that the change of the season, and the want of suitable nourishment, advertise these different species of birds to shift their abode. But whence did they learn that they should meet with, in other regions, a climate and aliment proper for them? In order to be able to answer these questions, and all such as may be asked on this interesting subject, we should carefully examine

every circumstance that attends the marches of these birds. The degree of cold or heat that accelerates, or retards them, deserves to be particularly attended to; for there is no room to doubt that they are most of all influenced by this. There is, perhaps, a secret relation between the temperature which suits with certain species, and that which is necessary for the production of the food that nourishes them.

But we have not carried our enquiries deep enough into these different species of birds and fishes of passage.

10. Among the societies of brutes *improperly so called*, some depend on chance, or on the agency of men, if not altogether, at least in part. It is not so with respect to societies *properly so called*. They do not owe their origin to any human act, but solely to nature. The members that compose them are not only united by common necessities, and that for a short time, but they are so by a much stronger tie, which subsists to the death of the animal, or at least during a considerable part of its life! I mean, the natural preservation of the individual, or that of its family: both the one and the other are necessarily attached to the state of society. It is for this great end that these different species of social animals have been instructed to labour in common on works so worthy of admiration.

Societies *properly so called* may be divided into two classes: the first comprehends those *whose principal end is limited to the preservation of individuals*; the second, those *whose scope is the preservation of individuals, and education of their young*.

Several species of caterpillars, and some species of worms, belong to the former of these two classes; ants, wasps, bees, beavers, to the second.

The first class will have under it two principal sorts; one of which will comprehend *temporary* societies; the other, societies *for life*.

11. A butterfly deposits her eggs about the middle of summer on the leaf of a plumb-tree; the number of these eggs is three or four hundred. After some days, there issues from each of them a very small caterpillar. They are so far from dispersing themselves on the adjoining leaves, that they all continue together on that whereon they first received their being: the same spirit of society unites them. They apply themselves immediately, in concert, in the spinning of a web, which at first is very thin; but they afterwards make it stronger, by gradually adding new threads to it: this web is a real tent spread upon the leaf, under which the young caterpillars shelter themselves. As they increase in bulk, they extend their lodging by fresh layers of leaves and silk: the spaces contained between these layers are apartments, all of which communicate by doors made on purpose. In this nest they pass the winter, placed near each other, without motion, till the returning spring enlivens them, and invites them to brouze on the sprouting leaves. Lastly, towards the month of May, the society is dissolved; every caterpillar separates from his companion, and spends the remainder of his life in solitude: being then become stronger, a state of society is no longer necessary for them.

12. The caterpillars that live on the oak, and whose societies are much more numerous than those of the *common,* are very singular in their proceedings. They set out from their nest at sun-set, and march in procession, under the conduct of a chief, whose motions they follow: the ranks are at first composed only of one caterpillar, afterwards of two, three, four, and sometimes more. The chief has nothing in him that may distinguish him from the rest, but by being the first, and that he is not constantly, because every other caterpillar may, in his turn, occupy the same place. After having taken their repast on the leaves around them, they return to their nest in the same order; and this continues during the whole life of the caterpillar. When they have ar-

rived to their full growth, each forms for himself a cone, where it is transformed into a chrysalis, and afterwards assumes the form of a butterfly. These metamorphoses cause a new kind of life to succeed to the state of society, which is very different from the primitive one.

This is an example of societies *for life,* whose principal end is the preservation of individuals.

13. There are several kinds of caterpillars that are true republicans, and whose discipline, manners, and genius, diversify them as much as those of different people. Some of them, like savages, make themselves hammocks, in which they take their meals, and even pass their whole lives: others live like the Arabs and Tartars, in tents, which they erect in the meadows; and when they have consumed all the herbs that grew about them, they go away and pitch their camp elsewhere.

The nests which the republican caterpillars make for themselves are perfect retreats; they are screened in them from the injuries of the air, and are all closely shut up in times of inaction or idleness; but they go out at certain hours to seek their nourishment. They feed on the leaves which surround them, which they consume one after another: they often go to a great distance from their dwelling, and by different turnings. However, they can always find it again, when they have occasion: nature has provided them with a method for regaining their lodging, which answers exactly to that used by THESEUS for fetching ARIADNE out of the labyrinth. We pave our ways; our caterpillars line theirs with tapestry: they never walk but on silk carpets. All the paths that lead to their nest are covered with silk threads: these threads form tracks of a glossy white, which are at least two or three lines in width. By pursuing these tracks in a row, they never lose their way, how intricate soever the turnings and windings of their passage may be. By putting a finger on the track, we should intersect the path, and throw the caterpillars into the greatest perplexity: they stop on a sudden at this place, and express all the signs of fear and distrust. Their march is suspended, till some caterpillar, more bold than the rest, crosses over the spoiled path: the thread she spreads in crossing serves as a bridge for the next to pass over. This, in passing, spreads another thread; a third another, and thus the way is soon repaired.

Yet there is a great difference between the method of the republican caterpillars, and that of Theseus. They do not spread a carpet over their paths to prevent their missing their way; but they do not miss their way, because they spread such a carpet: they spin continually, because they have always occasion to evacuate the silky matter, which their nourishment produces again, and which is inclosed in their intestines. By satisfying this want, they are assured of being in the right path, without attending to it. The construction of the nest is likewise connected with this want. Its architecture is adapted to the form of the animal, to the structure and exercise of his organs, and to his particular circumstances.

14. Ants seek their provisions and aliment at a great distance from their abode: various paths, which are often very winding and intricate, terminate at their nest. The ants pass over them in rows, without ever missing their way, any more than the republican caterpillars: like the latter, they leave tracks wherever they pass. These are not discernible to the eye; they are much more sensible to the smell; and it is well known that ants have a very penetrating one. However, if we draw a finger several times backwards and forwards along the wall by which the ants pass and repass up and down in rows, they will be stopped on a sudden in their march, and it will afford some amusement to observe the perplexity they are in. It will happen in the same manner with regard to the processions of these ants, as

has been before related, concerning those of the cater-pillars.

15. The sight of a bee-hive is certainly one of the finest that can offer itself to our eyes: there appears in it an astonishing air of grandeur. One can never be weary of contemplating these work-shops, where thousands of labourers are constantly employed in different works. We are struck in a particular manner with the geometrical exactness of their works; as we likewise are at the sight of their magazines, which are replenished with every thing necessary for the support of the society during the rigorous season. We likewise stop with pleasure to behold the young ones in their cradles, and to observe the tender care of their nursing mothers towards them.

But what chiefly attracts the attention is the queen: the slowness, I had almost said gravity, of her march, her stature, which is a more advantageous one than that of the other bees, and, above all, the various homage paid her by the rest. We can scarcely believe what our eyes are witnesses of, in the regard and assiduities of the neuters for this beloved queen. But our amazement is greatly heightened when we see these laborious, active insects, entirely cease from their labour, and suffer themselves to perish, as soon as they are deprived of their sovereign.

By what secret engagement, by what law superior to that whereby each individual provides for its own preservation, are the bees attached to their queen in such a degree, as absolutely to neglect the care of their own lives, when they happen to be separated from her? This law seems to be nothing more than the grand principle of the preservation of the species: the neuters do not engender, but they know that the queen enjoys that faculty; they construct those cells, whose proportions we so much admire, for the reception of the eggs she is ready to lay. Nature has instructed them as-much with regard to the young that is to be hatched from them, as she has the mothers of other animals in favour of their offspring.

16. Of all animals that live in society, none approach nearer to human understanding than beavers. We are at a loss to determine what is most worthy of admiration in their labours, whether the grandeur and solidity of the undertaking, or prodigious art, fine views, and general design, so excellently displayed throughout every part of their execution. A society of beavers seem to be an academy of engineers, that proceed on rational plans, which they rectity or modify as they judge necessary, pursuing them with as much constancy as precision; all are animated by the same spirit, and unite their will and strength for the promoting one common end, which is always the general good of the society: in a word, we must be witnesses of their performances, before we can judge them capable of them. A traveller that is ignorant of them, and happens to meet with their habitations, will think he is among a nation of very industrious savages.

The mole, or bank, which they raise, is a work of immense labour; and it is inconceivable how brutes are able to project, begin, and complete it. Represent to yourself a river of fourscore or a hundred feet in width. Their first business is to break the force of the current: the beavers then throw up a bank, or causeway, eighty or a hundred feet in length, by ten or twelve feet at its base. Nothing is more certain than this, nor less likely; and when we have repeatedly seen it, we are still willing to renew our inspection of it, in order to enforce our belief.

The most considerable towns of the beavers consist of twenty or twenty-five lodgments, though such are but rare; the most common have only ten or twelve.

Each republic has its peculiar district, and admits of no accidental guests.

When any great inundations damage the edifices of the beavers, all the societies, without exception, unite together for making the necessary repairs. If hunters declare a cruel war against them, and entirely destroy their banks and cottages, they disperse themselves about the country, betake themselves to a solitary life, dig burrows or trenches under ground, and never shew any marks of that industry we have been admiring.

17. Beavers seem to be formed with a view to confound our reasonings. Their associating themselves into great bodies, for working in concert on their immense works; their separating into little families, or particular societies, charged with the construction of the huts; the nature of these works, their extent, solidity, propriety, and appropriation, so conducive to one general end, comprehending such a number of subordinations: in a word, their almost perfect resemblance with works erected by men with the same intent, all concur to give the labour of the beavers an undoubted superiority over that of the bees. In fact, to fell trees chosen on purpose, to lop them, and cut off their projections, to make great cross pieces of timber of them, disposing them in their proper places; to cut smaller trees like stakes, plant several rows of these stakes in a river, and interlace them with branches of trees, in order to strengthen and connect them together; to make mortar, and with it solidly to compact the inside of the pile: and to all this to add the form, proportions, and solidity of a great bank; to form sluices thereon, and open or shut them according to the water's elevation or abatement; to build behind the bank little houses, one or more stories high, founded on an entire pile-work; to build them solidly without, and incrust or cement them within by a layer of plaister, applied with equal exactness and propriety; to cover the flooring with a

verdant tapestry; to contrive lights and outlets in the walls for different purposes; to erect magazines, and supply them with provisions; to repair with diligence whatever breaches may happen to the public works, and re-unite themselves into one grand body for the effecting in common these reparations; are astonishing marks of industry, which seem to imply in the beavers a ray of that light, which raises man so far above the rest of the animal creation.

CHAP. XII.

Continuation of the Industry of Animals.

1. WE shall, in the next place, treat of the proceedings of *solitary* animals. If they do not affect that extraordinary air of reflection and prudence, that brightness of genius, and that appearance of policy and legislation which we admire in *sociable* animals, they nevertheless attract our regard, either by their simplicity and singularity, or their diversity and appropriation to one common end, for the attaining of which they use the ingenious and natural means. After having contemplated the government, manners, and labours, of a *republican* community, we may still find some pleasure in considering the life and occupations of a *solitary* one; thus passing from the monuments of *Rome* to the cottage of a *Robinson*. Those works that are performed by the sociable animals, and which astonish us as much by their size, as by the beauty of their disposition, result from the concurrence of a number of individuals: they all pass through various hands; some sketch them, others bring them to a greater perfection, and a third sort finish them. The works of solitary animals spring from one head only; and the same hand that begins them, continues, finishes, and repairs them. Each individual has his particular talent and degree of skill, whereby he provides for his own subsistence, and furnishes himself with all necessaries.

We will here confine ourselves to the proceedings relative to the *metamorphosis*. This is an affair of great importance for one of our hermits to prepare himself for, the most interesting to him of any during his whole life. *Caterpillars* alone exhibit to us the examples of almost all the proceedings which nature has taught to insects of this kind. We will limit our examinations to this class in particular.

2. There are some caterpillars whose bodies are supported by a prop, and nature has taught them the method of effecting this. They wind a girdle round their body, composed of a number of silk threads collected together, whose edds are fixed to the prop that sustains them: by this means they fasten their hind legs in a little heap of silk. It is easy to imagine after this, that the chrysalis must be tied and grappled as the caterpillar was: the girdle is loose, and leaves the chrysalis sufficient room to perform its little operations.

3. Other caterpillars form cones. Some of these give their cone a more exquisite form, so as to resemble that of an inverted boat. The cone of a silk-worm is made, if we may be allowed the expression, of a single piece. The cones made boat-wise consist of two principal parts, shaped like shells, and joined together with great skill and propriety: each shell is worked separately, and formed of an almost infinite number of very minute silk rings. On the fore part of the cone, which represents the hind part of the boat, is a ledge that juts out a little, in which we may perceive a very narrow crevice, which denotes the aperture contrived for the exit of the butterfly: by means of that, the two shells may part asunder, and leave room for the butterfly to pass through them. They are constructed and put together with so much art, that they are of the nature of a spring; and the cone from whence the butterfly has lately issued, appears as close as that which it still inhabits: by this ingenious artifice the butterfly is always free, and the chrysalis in safety. We shall hereafter come to treat of proceedings which are analogous to these, but more singular.

4. Our spinners have not all an equal provision, yet all seem to endeavour at concealing themselves from sight. Such as are not rich enough to make themselves a good lodgment of silk, supply the want of it by different matters of a coarser or finer texture, which they are sufficiently skilful to cause to contribute towards the construction of the lodge. Some content themselves with giving it a covering of leaves, which they connect together without any art. Others do not confine themselves to the amassing these leaves, and disposing them indiscriminately, but range them with a kind of regularity. Others think proper to powder the whole of their cone with a matter they yield from behind them, and which they cause to penetrate betwixt the thread. Others strip themselves of their hairs, and form a mass of a mixture of silk and hairs. Others, after having stripped themselves, plant their long hairs about them, and make of them a sort of cradle-fence. Others add a greasy matter, which they procure from their inside, to the silk and hairs; with this they stop up the rings of the weft, and it serves as a varnish for them. Others thrust themselves into sand, or small gravel, and there construct for themselves cones of sand, whose grains are connected with the silk. Others, lastly, which have no silk, pierce the earth, make a cavity in it like a cone, and smear the sides of it with a kind of glue, or paste.

Another species, which is far more industrious than the former, perform a work which we cannot too much admire. You have lately seen described those cones which resemble an inverted boat: this is likewise the form that this species give to their cone; but they do not make it entirely of silk. They strip off little pieces of bark with their teeth, of a rectangular figure, nearly even and alike, and dispose them with all skill and propriety; with these they compose the principal parts of the cone. These great parts are likewise formed of a considerable quantity of very small inlaid work, placed end to end, and joined together with silk. In a word, we are apt to fancy that we are looking at an inlaid floor, or a piece of inlaid work.

5. The most solitary of all insects are such as live in the inside of fruits. Each fruit lodges only one caterpillar, or worm: we are ignorant of the cause of this remarkable fact. We only know, that a curious observer having attempted to cause caterpillars of this species to live together, they furiously engaged each other as often as they met: it is then incontestibly true, that the disposition of these caterpillars is anti-sociable. Several have metamorphosed themselves in the very fruit that has served them for a retreat and for provision; they dig cavities in it, which they line with silk, or in which they spin their cones. Others, which are the greater part of them, quit the fruit, and metamorphose themselves in the earth.

6. Those insects that roll up or fold the leaves of a great number of plants, are also perfect hermits: this proceeding is common to many caterpillars. They thus procure for themselves little cells, which are convenient lodgings for them, in which they are always sure to find nourishment, for they eat the walls of the cell; but they are always very careful never to touch that part which is destined to cover them. The different methods in which these caterpillars lodge themselves, give room for distinguishing them into *tyers, folders,* and *rollers.*

The art of the *tyers* is in general the most simple. It consists in joining several leaves together with silk threads, in order to form them into one entire parcel, in the centre of which is the lodge of the little hermit.

The procedure of the *folders* supposes more refined operations. They fold the leaves either *in the whole,* or *in part.* In the *whole,* when the portion folded is turned back flat upon another part of the leaf: and in *part,* when they only simply bend the leaf more or less.

But the labour of the *rollers* is most of all to be admired. They live in a kind of roll, whose dimensions, form, and position, vary in different species. Some give it a cylindrical figure; others, the form of a cone, which is likewise as well made as those the grocers use. The leaf is always rolled spirally, or as *wafers* are. The roll, or cone, is commonly laid on the leaf; but sometimes, which is very remarkable, it is fixed on it like a nine-pin.

Does my reader imagine that mechanism presides over the construction of these various works? Does he conceive in what manner an insect, that has no claws, is able to roll up a leaf, and to keep it so? We know in general that caterpillars spin: and can in some measure discover, it is by the assisstance of their threads that our skilful rollers cause the leaves to take the form of a cylindrical or conical tube. We see in effect parcels of threads distributed from one distance to another, which hold the roller confined to the leaf. But how can these threads, which seem only to perform the office of small cables, be capable of rolling up the leaf? This we imagine ourselves able to guess at, but without effect. We suppose, that by fastening threads to the edge of the leaf, and drawing these threads towards her, the caterpillar forces the edge to rise and turn itself; which is by no means the case. The use the industrious insect makes of its strength, consists of a more refined mechanism. He fixes a number of threads to the border of the leaf, but does not draw it to him. By means of them he bends the other extremity to the surface of the leaf. The threads of one and the same parcel are nearly parallel, and compose a little ribband. By the side of this ribband the insect spins a second, which passes over and crosses the former. This then is the secret of its mechanism. In passing over the first ribband in order to extend the second, it bears on the first with the whole weight of its body; this pressure, which tends to force down the ribband, obliges the edge of the leaf to which it is fastened, to rise. The second ribband, which is at the same time struck on the flat part of the leaf, preserves on the edge that alteration or bending which the insect was disposed to give it. If we narrowly examine these two ribbands, their effect will be visible. The second will appear very tight, and the first very slack; the reason is because the latter has no greater degree of action, nor indeed ought to have. You now comprehend that the roll is gradually formed by the repetition of the same operations on different parts of the leaf. But it often happens that the coarser edges resist too much; the insect knows how to weaken them by gnawing them here and there. In order to form a *cone,* some more performances are necessary. The *roller* cuts with her teeth, on the leaf, the part that is to compose it. She does not detach it altogether from it; it would then want a base; she only separates that part which is necessary to form the foldings of the *cone.* The part is properly a slip, which she rolls as she cuts it. She raises the cone on the leaf, almost in the same manner as we erect an inclined obelisk. She fixes threads or little cables near the point of the pyramid; she presses on them with the weight of her body, and thus forces the point to raise itself. You may form an idea of the rest; the mechanism is the same as that employed in making a roll.

These cells, in which the caterpillar lives, serve likewise as a retreat for the chrysalis. This latter would not probably be sufficiently well accommodated with a bare covering of leaf. The caterpillar lines the cell with silk tapestry. Other species spin a cone for themselves in it.

7. Some leaves of plants are scarcely thicker than paper. Would any one imagine there were insects skilful enough to provide a lodging in such thin leaves as these, so as to shelter themselves from the injuries of the weather? A leaf is to them a vast country, wherein they make roads for themselves that are more or less winding; they mine in the substance of the leaf, as our miners do in the earth. From hence also they have taken the name of *miners of leaves.* They are extremely common: some belong to the class of cater-

pillars; others to that of worms. They cannot bear to be naked; and it is for the sake of covering themselves that they insinuate themselves between the two foldings of a leaf. They find their subsistence there at the same time. They eat the pulp of it, and in eating, trace out a way for themselves. Some dig there strait or crooked trenches. These are *gallery* miners. Others mine round about them, in circular or oblong spaces, these are *miners* at large. Their teeth are the instruments they mine with; but some worm-*miners* dig by means of two hooks resembling our pick-axes. Several of these insects spin within the mine, the cone wherein they are to transform themselves. Others quit the mine, and metamorphose themselves elsewhere. Butterflies that proceed from a *mining* caterpillar, are little miracles of nature. She has lavished gold, silver, and azure upon them; with other colours that are more or less rich; though we regret that she has not performed these master-pieces in a more extensive form.

8. But *miners* have something still more wonderful to offer us. Bestow your attention on those vine leaves that are before you. They are pierced with *oval holes* which seem to be made in them by a *gimblet.* The *mining* caterpillars bored these holes, by stripping two pieces of skin from the leaf, with which they make a cone: that cone is there placed perpendicularly on a vine-prop, at a pretty considerable distance from the leaf that furnished the materials. How was it cut, fashioned, detached, and conveyed? Let us not vainly attempt to guess this: let us rather endeavour to surprise the industrious labourer on her working bench. She mines *by way of gallery,* and constructs her cone at the extremity of the gallery. It is composed of two pieces of leaf of an oval form, very thin, even, and like each other. The caterpillar prepares these places; makes of them a thin texture, by clearing them of the pulp; she models them, lines them with silk, cuts them with her teeth, as with scissars, joins and unites them. They already have no connection with the leaf, notwithstanding

which, the cone does not fall: the caterpillar has taken the precaution to sustain it by some threads of the same species with its border. When the cone is finished, the caterpillar applies herself to disengage and transport it from its place. She has left a small aperture at one end of it. She causes her head to come out at this opening, bears it forward, seizes a part of the prop with her teeth, and by an effort draws the cone to her. The threads that hold it give way, and the caterpillar carries her little house about with her as the snail does her shell. Behold her walking; her march is a new mystery. It has been said that all caterpillars have at least ten legs: this is absolutely without any, and shews us what an opinion we ought to entertain of such naturalists. Let us lay in her way a finely polished glass, placed perpendicularly. She is not in the least retarded by this, but climbs over the glass as on a leaf. By what secret art is she enabled to cleave to it, for she has neither legs nor claws to grapple it? You have seen caterpillars that spin little heaps of silk which they fix themselves to. Our *miner* spins the like, at certain distances, according to the track she is to pass over. She seizes one of these heaps with her teeth, which becomes in part a support for her; she draws the cone to her, and carries it towards the little heap: fastens it to it; thrusts her head forwards: spins a second heap: fixes herself to it in the same manner as to the first; makes an effort to discharge the cone, which she effects, drags it towards the new heap, fastens it likewise to it, and this second step being taken unravels to you the secret of her ingenious mechanism. By this means she leaves on the bodies over which she passes little tracks of silk, which she spins from space to space. When she has arrived at the place she is inclined to fix herself at, she here stops the cone intended for a habitation, and places it in a vertical situation. There afterwards issues from it a very pretty butterfly, as richly clothed, and of the same genus, as those of other miners.

9. Other insects live in great galleries of silk, which

they lengthen and widen as they grow: They cover them with gross matter, and frequently with their excrements. They construct those galleries on the various bodies they feed upon, and which differ according to the species of the insect. The name of *false moths* has been given to all such species as make those enclosures. You are sensible, that those of *true moths* are portable. The most remarkable false moths are such as settle in bee-hives, and destroy the combs. They are without defensive arms, and are only secured with a soft and delicate skin; notwithstanding which nature has appointed them to live at the expence of a little warlike people that are well-armed, and equally well disposed to defend their settlements. Our engineers have frequently recourse to mines and saps in the reduction of places. It is indeed abundantly necessary that our false moths should excel in this kind of attack, and their works prove that they do. They never march but under cover. They scoop long trenches in the thick part of the combs, in what direction they think proper, wherein they are always in safety from the enemy. The galleries of this kind are lined within with a very close silk tissue, and covered on the outside with a thick layer of grains of wax and excrements. Thus the fine works of the laborious bees are destroyed in silence by an enemy which they are not able to discover, and that sometimes compels them to abandon their hive. The false moths have no intention to procure honey: they never penetrate into the cells that contain it. They only eat the wax, and their stomach analyses the matter which the chymist cannot dissolve. When they have attained their full growth, they make a silk cone at the end of the gallery, which they never fail to cover with grains of wax.

Other false moths establish themselves in our granaries, where they multiply excessively. They covet our most valuable commodity. They connect together several grains of corn; they spin a little tube in the midst of this heap, where they lodge. By that means they are always within reach of a plentiful stock of nourishment. They feed at their pleasure on the grains of which they have been careful to form their case, and which are like a covering to it. When their metamorphosis approaches, they abandon this case; they nestle in the inner part of a grain, or in the little cavities they dig in the cielings: these they line with silk, and there transform themselves into a chrysalis.

10. There are few insects which claim so good a right to our admiration as those that are equally skilful with ourselve in making clothes, and that undoubtedly learned the art before us. Like us, they are brought forth naked; but they no sooner come into the world, than they set about clothing themselves. They do not all dress in the same uniform manner, nor do they use the same materials in their clothing. There is perhaps a greater diversity with respect to this in the modes of different species of moths, than in those of different people on the earth. The form of their dress is very convenient: it corresponds exactly with that of their body. It is a little cylindrical case, which opens at both ends. The stuff is manufactured by the moth: the ground of it is composed by a mixture of silk and hair: but this would not be soft enough for the insect; it is therefore lined with pure silk. Our woollen furniture and furs supply these moths with the hair they employ in manufacturing their stuffs. They make a careful choice of these hairs, cut them with their teeth, and artfully incorporate them in the silk tissue. They never change their clothes: those they wore in their infancy, they continue to wear when arrived at maturity. They can then lengthen or widen them as they find convenient. They meet with no difficulty in extending them: this they do by only adding new threads and hairs to each end. But the widening them is not so easy a matter: they proceed herein exactly as we do in the like case. They slit the case at the two opposite sides, and skilfully insert two pieces of the width required. They do not slit the case from end to the other; if they did, the sides would start asunder, and be exposed:

they only slit each side about the middle of it. Reason itself could not exceed this. Their dress is always of the colour of the stuff from whence it was taken: if, therefore, a moth, whose clothing is blue, passes over a red piece of cloth, the widths will be red; she will make herself a harlequin's habit, if she passes over cloths or stuffs of several colours. They live on the same hairs they clothe themselves with. It is remarkable, that they are able to digest them; and it is still more extraordinary, that the colours do not suffer the least alteration by digestion, and that their excrements are always of as fine a tincture as the cloths they feed on. Painters may collate from our moths powders of all colours, and all kinds of shades of the same colour. They make little journies: those that settle in cases, do not love to walk on long hairs, but cut all they meet with in their way, and are always provided with a scythe as they march. They rest themselves from time to time, when they fix this case with small cords, and thus cause it, as it were, to ride at anchor: they fasten it more firmly, when they are disposed to metamorphose themselves. They close up entirely both ends of it, in order to clothe in it the form of the chrysalis, and afterwards that of the butterfly.

11. *Field* moths greatly exceed the *domestic* moths in point of industry. They take the substance of their clothing from the leaves of plants; but it becomes necessary for them to prepare this matter, and give it that lightness and flexibility proper for the garments. These moths are of the species of *miners*; and they insinuate themselves betwixt the two membranes of a leaf, which are to them what a piece of cloth is to a taylor; with this difference, that the latter has occasion for a pattern, which the moths can dispense with. They remove from these membranes all the pulpy substance that adheres to them, which membranes they make thin, and polish. They afterwards cut in them, thus prepared, two pieces, which are nearly equal, and like each other; they labour to give them the hollowness, windings, and pro-

portions, which the form of their case requires, and this form is often of an exquisite kind. They connect and unite them with incredible skill; and conclude by lining them with silk. They have then nothing to do but disengage the clothing from within the leaf where it was taken and cut, and that requires but a few efforts.

12. Many *field* and *aquatic* moths do not prepare the stuff for their clothing. Bits of wood, little sticks, fragments of leaves, pieces of bark, &c. placed on each other like tiles, compose the external clothing of the case, which consists of pure silk. At other times it is covered with gravel, pebble-stones, pieces of wood, little bits of reed, and small shells, either of muscles or snails; and, what is scarce credible, the snails and muscles continue to live in these shells; for, being in a manner chained to the case, they are obliged to follow the moth, that carries them wherever it pleases. Thus, a moth in its clothing, does not appear unlike certain pilgrims: those that are covered with wood, gravel, stones, and other unwieldy matters connected together, pretty nearly resemble a Roman soldier in heavy armour. You rightly judge, that such kind of clothes must needs be very roughly formed: but some of them nevertheless look very pretty, in which the arrangement of the materials makes amends for their coarseness. Aquatic moths reap some advantage by dressing themselves in such a strange manner. They must be always in equilibrio with the water, in the midst of which they live. If their case prove too light, they add a little stone to it; if too heavy, they fasten some bits of reed to it. All these moths metamorphose themselves in their case; some into butterflies, others into flies, and others into beetles.

13. Some *field* moths borrow no strange matters to clothe themselves with; they dress entirely in silk; but their tissue is much closer, finer, and more glossy, than that of the most beautiful caterpillars. It has a still greater singularity; being composed of little scales, like

those of fishes, partly placed on each other. The case has sometimes for its last covering a kind of mantle, which almost entirely incloses it, and is composed of two principal pieces, whose figure resembles that of a *bivalve* shell. Moths that procure the matter for their clothing from their own fund, must be able to lengthen and widen it at pleasure; the expense attending the obtaining of it was too great to admit of their making a new one as often as there should be occasion: so that they are able to enlarge it in a wonderful manner. They do not add *breadths* to it as the domestic moths do; but slit it from one part of it to another, according to its length, and immediately fill up the intervals with new threads, of a length proportioned to the space required. This case serves them likewise as a kind of cone, wherein they transform themselves into butterflies.

You have taken a survey of the produce of a multitude of different insects, and are with good reason astonished at the prodigious variety contained in them, all relative to one and the same general end, and all of them likewise as much diversified as those of our artizans. How does it happen, that amongst so many insects as prepare themselves for their metamorphosis, some hang by their hind part, others fasten themselves with a girdle, whilst others make themselves cones? How came it to pass, that of those that construct these cones, some form them of pure silk, and others compose them of matter of different kinds? Why is the form of these cones so various in different species? Wherefore do some insects so artfully roll up the leaves of plants, and others only fasten or fold them together? How can we account for the mining of these leaves by some only, and that the rest should not all mine them in the same manner? In short, how shall we assign a reason why the moths are not all clothed in the same dress?

All these *wherefores*, and a thousand others that may be formed on the productions of nature, are so many enigmas proposed to beings that are banished into a corner of the universe, and whose sight, as short as that of the mole, can only perceive the nearest objects, and the most direct and most striking relations.

It behoves us to remain in the place that has been allotted for us, from whence we can only discover some links of the chain. One day we shall discover more of them, and shall see them more distinctly. Meanwhile we may consider these proceedings of insects, so diversified and replete with industry, as an agreeable spectacle, exhibited by nature to the eyes of the observer, that furnishes him with an inexhaustible source of reflective pleasure and useful instruction. He is led to the AUTHOR of the universe by the thread of the caterpillar, and he admires in the variety of their means, and in their tendency to the same end, the fecundity and wisdom of the ORDAINING MIND.

This sight becomes still more interesting, when the observer undertakes to bewilder insects, and draw them from their natural track: they then shew him resources which he had not foreseen, and that surpass his expectation. When false moths, of the wax species, are in want of wax, they can make galleries of leather, parchment, or paper. A caterpillar has been seen to construct a cone of little pieces of paper which have been given him, and that have been cut at pleasure: it has taken hold of them with the teeth and fore legs, transported them to the place where it intended to fix, ranged them there, fastened them with threads, laid some of them edgewise, others flat; forming of the whole, it is true, an assemblage that appears a little strange, but answering perfectly to a cone. It would have given it a more regular figure, had it worked with materials suited to its species. Ere we had learnt to prepare and dress woollens and skins of animals, the *domestic* moths were not without clothing; they were then perhaps habited in the same manner as the *field* moths.

14. We do not expect to make any material discoveries from *shell-fish* that are shut up in an almost stony inclosure; they seem very stupid; but they are not all so senseless as they appear to be: we shall with pleasure contemplate the proceedings of some of them.

Divers species of sea shell-fish are furnished with two pipes, by means of which they suck in the water, and which they take great care to keep raised above the vessel they are accustomed to sink into more or less. Some spurt out the water to the distance of several feet. That particular part which in some performs the progressive or retrograde motion, very much resembles a real leg with a foot joined to it; but this leg is a Proteus, which assumes all kinds of forms to supply the necessities of the animal. It does not only make use of it to crawl with, sink into a vessel, or retire from it; but employs it with much greater skill to perform a motion that one would not imagine a shell-fish capable of. A shell-fish that leaps, must appear very extraordinary: it is a *tellina* that you are now seeing. You may observe that she has placed the shell on the top, or point. She stretches out her leg as far as possible; she causes it to take hold of a considerable part of the circumference of the shell, and, by a sudden motion, similar to that of a spring that is slackened, strikes the ground with her leg, and thus leaps to a certain distance.

15. The *cutler* never creeps: it penetrates perpendicularly into the sand. It there digs itself a sort of cell, which is sometimes two feet long, in which it goes up and down at pleasure. Its shell, whose form a little resembles that of the handle of a knife, has occasioned it to receive the name of *cutler*: it is composed of two long pieces, hollow like a gutter, and joined toge-

ther by membranes. The body of the animal is inclosed in a case. The part whereby it exercises all its motions, is placed in the centre. This is principally designed to perform the office of a leg, and acquits itself exceeding well: it is fleshy, cylindrical, and pretty long. The extremity of it, when necessary, can roll itself up like a ball. View the cutler when extended on the sand: you behold it working, in order to pierce into it. It thrusts out its leg at the lower end of the shell; stretches it, and causes the extremity of it to assume the form of a shovel that is sharp on both sides, and terminates in a point: it directs it towards the sand, and applies the edge and point for introducing it farther. After the aperture is made, it extends its leg still more, and causes it to penetrate deeper into the sand: he bends it like a hook, with which taking hold of a support, he draws the shell to him, forcing it upright by degrees, and afterwards causes it to descend into the hole. Is he disposed still to continue sinking? He thrusts his whole leg out of the shell; fixes in the sand the ball which is then at its extreme part; immediately contracts this leg; his large head, which is strongly fixed in the hole, being less inclined to re-ascend than the shell is to go downwards, the cutler descends into the sand, which is his first step into it: he has nothing to do but to repeat the same operations, in order to advance farther and farther into it. Is he disposed to go up again to the surface? He pushes forth the ball, and at the same time makes an effort to extend his leg; the ball, which is averse to a descent, presses the shell towards the top of the hole. It is pretty remarkable, that the cutler, which lives in salt water, dreads the touch of salt: if a pinch of it be cast into his hole, he will come out of it immediately. But if he be caught, and afterwards permitted to re-enter his cell, it will be in vain to throw salt into it, since he will not quit it on that account. It is said by some, that he remembers having been taken; and this is so true, that when people do not catch him, he may be made to come out at one's pleasure, by throwing some fresh salt into the hole. It seems, then, that he is aware of the snare that is laid for him, and is unwilling to be taken by it.

16. Cast your eyes on this stone, which I have just now taken up from the sea-shore. A shell-fish fixes his habitation in it. Observe, that on the surface of the stone there is a very little hole; it is by that the shell-fish has entered, and you may judge of the smallness of it by that of the aperture. We will break the stone asunder, that we may see the animal that dwells in it. How great must your suprise be! You behold a great shell-fish, near three feet in length, whose shell is formed of three smooth pieces, joined together by a ligamentary membrane. It is lodged in a great cavity, that is hollow like a funnel: the upper part of the cone is in the little hole you see on the surface of the stone. This shell-fish is a *dail,* or pholas. How could it be able to pierce so hard a stone? Or how go through so narrow a passage? Draw near this clayey shell which the wave has just left. It is pierced through with a multitude of such holes as you see in the stone you have in your hand. All these holes are inhabited by young dails, which are only a few lines long: they had then no occasion to penetrate into a hard stone. Moist clay makes but little resistance. But the sea insensibly converted this clay into stone: the dail, which at first found himself lodged in a soft earth, afterwards perceived that he was within a stone cell. We have seen that the cutler can come out of his hole when he pleases: the dail never quits his; nor indeed can he; since the form of this kind of cell will not admit of it. All that he can do is, to stretch out two pipes at the opening of the hole, with which he receives and rejects the water: the cutler does the same. You are impatient to be informed of the instrument with which the dail hollows his cell: this instrument has no edge to it; it is purely fleshy, and shaped like a lozenge.

17. We will quit shell-fish for a time. Divers animals of the sea will likewise entertain us with the won-

ders of their Author. Let us bestow on them the attention they deserve: what we are about to relate concerning them, will be found well deserving notice in natural theology.

On the rocks near the sea-shore you may perceive little fleshy masses, of the size of an orange, whose form is like that of a counter-bag, and pretty nearly resembling that of a cone when cut. All these masses seem immovable, and connected with the rock by their base: some of them are rough, others smooth. We have just now compared them to a bag or purse, in which counters are put; but this bag is not folded together, and is likewise without strings. They are nettles that you see, a very singular kind of animals, that demand a closer attention. The body of the animal is, in effect, inclosed within a sort of fleshy purse, of a conic figure: at the top of the cone is an opening, which the nettle increases or contracts at pleasure.

Let us consider the *sea-nettles* that we have now before us. There is one that opens and unfolds itself like a flower: it has put forth a hundred and fifty fleshy horns, like those of snails, distributed in three rows round the aperture. You remark, that little water-spouts issue from these horns; consequently they do not perform the same functions as those of snails; they are analogous to the pipes of dails, cutlers, and other shell-fish which you have seen. You also remark, that the form of these nettles varies greatly; that their base is sometimes circular and sometimes oval; and that the height of the cone varies according to the dimensions of its base: it rises or falls as the base grows narrower or wider. Touch one of these blown nettles: see with what quickness it closes and contracts itself. But you perceive no progressive motion: are the nettles then condemned to pass their whole life fixed to the same spot? The ancients thought so. What are we to think of them? About an hour ago, this large nettle, which you see on your right hand, touched this point of the rock: observe that it is now above an inch distant from it. You are surprised that you did not perceive it walk, for you looked at it more than once; the reason of this is, because its progressive motion is as slow as that of the hand of a clock. We may be curious to know how the nettle performs it. All its body is externally furnished with various orders of muscles: those of the base go, like rays, from the centre to the circumference; others descend from the top towards the base. These muscles are also canals, full of liquor, which issues out on pricking them: they are emptied and filled at the pleasure of the nettle. By the exercise of these muscles, or canals, the progressive motion is performed. Let us follow the nettle when she is disposed to go forwards. Her base is circular. She swells the muscles that are on that side whither she is tending. She injects her liquor into them, which, by inflating, lengthens them. They cannot extend themselves unless the edge corresponding with the base shifts its place, and advances a little way: at the same time she loosens the opposite muscles, and empties their canals. They contract. This they cannot do, except the edge of their corresponding base goes in a little, and exactly in the same degree as the opposite one projects. Such is the mechanism whereby the first step of our nettle is performed. In order to make a second, she causes the base again to receive a circular form, by puffing up equally all the canals: she afterwards repeats the same operations we have just taken a view of.

The whole progressive motion of nettles is not confined to this. They have another method of walking, which more nearly resembles that of insects: they are able to make use of their horns like legs. But these horns are on the upper part of their body: the nettle is fixed by its base against the rock: How do these horns perform the office of legs? The nettle you are following will shew you the method. She turns herself upside down; the base abandons the rock, and the cone is placed on its top: all the horns shoot forth, and you see them fix themselves to the rock. They are gluy and rough to the touch; for which reason they meet with no difficulty in fastening to it.

18. Would you believe that an animal which is entirely of a fleshy nature, and is provided with no instrument to open or pierce the shells, feeds upon shell-fish?

Nettles that are but of a middling size swallow great shell-fish; and it is difficult to conceive how they are capable of being lodged within the nettle. It is true, the latter being entirely fleshy, is susceptible of a great distension. It is a sort of supple purse, that may be stretched occasionally: the opening of the purse is properly the mouth of the nettle. Its inside not being transparent, one cannot see what passes therein, or by what means the nettle voids the shell-fish. The moment she has swallowed it, she closes herself. Look at this young nettle that is shut up quite close: she has just swallowed a pretty large snail, and is busy in digesting it. She is now opening herself again, and discharging the empty shell. On the side of her is another nettle, which bespeaks your attention: she has swallowed a great muscle, and is making ineffectual efforts to void the shell. She is not able to effect it: the shell presents itself in an unfavourable position at the aperture, and you begin to be in pain for the unhappy nettle: she has a resource that you did not imagine. Cast your eyes towards the base; the shell is evacuated through a large wound; the nettle is delivered from it by that means, and is no more affected by the great gash made thereby, than we are by a scratch.

19. All nettles do not procure a discharge by so violent method; they have another, which they commonly use with success. They turn themselves inside out, like a glove or stocking, so that the edges of the opening, which resemble lips, fold themselves on the base: the mouth is then of a prodigious width, and the bottom of the purse almost uncovered.

M. 5

Nettles do not thus shift themselves merely to get rid of heterogeneous bodies; they put themselves into the same posture when they bring forth. They are viviparous. The young are produced completely formed; and we see nettles in miniature appear. The aperture through which they pass, is so wide as to admit a multitude of them at the same time: notwithstanding which, they always come forth singly. They are at first inclosed in certain folds, concealed at the bottom of the purse.

Do nettles resemble polypuses by the singular property of being multiplied and grafted by slips? Experiments have put this beyond all doubt. Of a single nettle, divided according to its length or width, are made two or three, which at the end of a few weeks are perfect and complete. They may likewise be grafted; but it will be necessary to have recourse to *seaming*. You are now no longer surprised at the consolidation of that enormous wound made at the base of a nettle that issues out thereat. A wound of this nature is nothing, when compared to that which another animal sustains when cut in pieces, without ceasing to live and multiply in each piece. Nettles may then be called a species of *polypuses with arms* of a monstrous size; or, if you prefer the expression, *polypuses with arms* are a species of very minute *nettles*.

Let us quit these rocks that swarm with nettles, and betake ourselves to that little creek where the sea is very calm. Stoop a little, and observe the surface of the water. What do you perceive? A kind of greenish jelly floating upon it. Its form is like that of a broad mushroom: it is near two feet in diameter. Take a piece of it betwixt your fingers; handle it for a few minutes: you will see it dissolve into water. The heat of your hand was sufficient to melt it. Does it enter into your thoughts that this jelly is a real animal, and even a species of nettle? It has been called *wandering net-*

tle, because it never fixes, and floats from one side to the other: its convex surface presents us only with an infinite number of little grains or nipples. But its inferior surface, which is concave, is extremely organized; in that we may see a great number of canals, which are regularly disposed, and made with great art, some being circular, and others disposed regularly, like the fellies of a wheel, and which are full of a watery liquor, which passes from one to the other.

This strange animal wanders about in the sea: it is specifically much heavier than water. He cannot therein sustain himself without the assistance of a spontaneous motion, which is worth observing, and cannot be seen but in places where the water is calm. It is so in this little creek, on the extremity of which we are sitting. Look with attention on the surface of that jelly which offers itself to your view: observe that it has certain motions, which you are tempted to compare with those of the *systole* and *diastole*. However, they are not the same: their only end is to cause the nettle to float. You see that in the systole kind, the surface of the animal becomes very convex, and that in the diastole it becomes suddenly flat and wide: such is our glutinous nettle's method of floating. When dried in the sun, it is reduced almost to nothing: we imagine that we see a little piece of parchment, or very transparent paste. There is no room to doubt that this species of nettle multiplies, like the rest, by slips; but I do not know that there has been any experiment made concerning this. A jelly must be attended with greater ease in regenerating itself than organized bodies of the same genus, that are of a more firm and close consistence.

20. There are no regular, or strange forms, of which the animal kingdom does not afford us models. Here is an animal whose form is precisely that by which we paint the stars in the firmament: it is nearly flat. From the middle of its body proceed four or five rays, which are almost equal, and resembling each other: its upper

surface is covered with a hard, callous, and very rough skin. In the centre of the inferior surface is placed the mouth, which is provided with a sucker, that the star makes use of to imbibe the substance of the shell-fish she feeds upon. Five small teeth, or pincers, hold it confined while she sucks them, and perhaps assist in the opening his shell. The legs of the star are a real curiosity: they are joined to her inferior surface, and distributed with symmetry in four rows, each consisting of seventy-six feet; so that each ray is furnished with three hundred and four feet, and the whole star with fifteen hundred and twenty. Yet, with such a number of feet, the star goes but little faster than the muscle, which has only one. These legs perfectly resemble the horns of the snail, both by their figure, consistence, and exercise. When the star is disposed to walk, she spreads her legs as the snail does her horns, and with the extremity of them seizes the various marine bodies on which she crawls. She commonly puts forth only one part of her legs; the remainder are kept in reserve against those necessities which may happen. The mechanism which presides over their motions is an illustrious proof of a Creative Mind. Let us open one of the rays by slitting it lengthwise, and we shall display the principal springs of the machine. An almost cartilaginous partition, made in the form of vertebræ, divides the whole ray: in every part of this partition you perceive two rows of little balls, like pearls of the finest water. The number of these little balls is precisely equal to that of the legs: thus you see that each ball answers to a leg. You can distinguish a limpid liquor in these balls; press your finger upon them; they empty themselves; the liquor passes into the corresponding legs, and they immediately extend themselves. The star then need only press the balls in order to spread the legs. But they are capable of contraction, and when they contract themselves, they force the liquor back again into the balls, from whence it may be driven afresh into the legs, to procure a progressive motion.

You conjecture that these eggs, which resemble these tubes, through which divers kinds of shell-fish respire, serve likewise for the same uses. But nature, who has been so lavish in providing the star with legs, has been also liberal in bestowing on it the organs of respiration; she has even multiplied them in a greater degree. They are very small conic tubes, disposed in knots, and produce an equal number of little water spouts.

Amongst our stars, you observe there are some which have only two or three rays: and by looking more narrowly at them, you discover several very minute rays, just beginning to shoot out. Are then animals, that are formed by a repetition of such a great number of parts, both outward and inward, regenerated like polypuses, whose structure appears so simple? Nothing is more true; and the stars you are now looking at will afford you proof of it. These animals often chance to lose two or three of their rays, and they are no more affected by this loss than polypuses are by parting with some of their arms. We may mangle stars, or cut them in pieces, but cannot destroy them by that method: they will recover from their ruins, and each piece becomes a new star.

21. *Sea-hedge hogs,* like the land ones, derive their names from their prickles. But those of the former are quite different from such as belong to the latter.

The form of these hedge hogs is that of a round button: it is hollow within, and its surface is elaborately wrought. We might compare the workmanship of them to that of certain copper, or wire buttons. A multitude of tubercles, like little triangles, divide the whole surface of the button: these triangles are separated by stripes, which are regularly spaced, pierced with holes, and distributed with great symmetry in several lines. These holes pass through from one part to another, the whole thickness of the skeleton; for the body of our hedge hogs is a kind of bone-box. Each hole is a socket, wherein is a fleshy horn, like those of a snail, and susceptible of the same motions: there are therefore, as many horns as holes, and there are reckoned to be at least three hundred. The hedgehog, like the snail, makes use of her horns for feeling the earth, and the various bodies it meets with in its passage: but it particularly employs them to fasten with and cast anchor. The tubercles are the bases of many prickles, or legs; and their number amounts to at least two thousand one hundred: so that there is hardly any part of the body of a hedgehog that is destitute of a leg. It can, for that reason, walk as well on the back as on the belly; and in general, let it be in what posture it will, it has always a great number of legs ready to carry it, and horns to fix it with. The legs it uses with the the greatest ease, are those which surround the mouth; but when it pleases, can walk by turning round on itself like a wheel. On the back or the top of the button, is another aperture which is thought to be the anus. This then is an animal that is provided with at least thirteen hundred horns, and two thousand one hundred legs. What a great number of muscles must it require to move so many horns and legs? How many fibres must there be in each of these muscles? What an astonishing multiplication of parts in this little animal? What regularity, what symmetry, and even harmony, in their distribution! What variety in their exercise!

When the hedgehog would advance, he draws himself forwards with those legs that are nearest the place he would go to, and pushes himself towards it with the opposite ones: all the rest remain at that time in a state of inaction. At the same time that one part of his legs are at work, the horns that are nearest to them exert themselves to sound the way, or find anchorage for the animal.

22. Most shell-fish are produced with their clothing: the shell they bear grows with them and by them. But *Bernard the hermit,* a kind of cray-fish, so called, comes into the world without a shell, though he has need of one in order to cover the greater part of his body; whose thin and delicate skin would suffer too much from

being naked. Has nature then behaved to it as a step-mother, by denying it so necessary a garment? By no means: as she is beneficent towards every other animal, so has this likewise been the object of her attention. It is true, she has not provided it with a shell; but has made it amends by enabling it to clothe itself with one. Taught by so great a mistress, our hermit has the sagacity to take up his lodging in the first empty shell he meets with: he applies himself indifferently to all that are of a spiral construction. He often retires so far into them, as not to be perceived, whereby the shell appears empty: if the shell should prove too narrow, he quits it in order to seek for another, more suitable to his bulk. It is said, there sometimes happen contests between our hermits about a shell, and that victory is decided in favour of him who has the strongest claws. Our battles have scarcely ever a cause of equal importance for their object.

23. You have been already astonished at the skill displayed in the progressive motion of several shell-fish; your amazement will be redoubled when you learn that some of them can spin: and you are impatient to see them at work. Let us walk on the sea-shore. You there discover a number of muscles, some by themselves, and others joined in companies. Consider them more attentively, you will observe that some of them are fastened to stones, or to each other, by a great number of small slender strings. Let us select one of these muscles, that we may observe it more closely, the better to discover their operations. Here is one of them endeavouring to fix itself to this stone that is near the surface of the water. The shell is partly open; it has thrust out from it a kind of supple tongue, which it lengthens and contracts alternately. Remark that it often applies the ends of it to the stone, and immediately draws it back again into the shell, that it may again put it forth the next moment. From the root of this kind of tongue there issue certain threads, which are equal in size to a hog's bristle. These threads part

from each other as they come out, and their extremity sticks to the stone: these are as so many small cables which hold our muscle at anchor. There are frequently a hundred and fifty of these little cables employed in mooring a muscle: each cable is scarcely two inches long.

The muscle herself has spun all these cords. The tongue not only serves them, as it does other shell-fish, for arms to fasten themselves with, and for legs to creep with, but is also the spinning instrument which produces those numerous threads, by means of which the muscle resists the impulse of the waves. From the root of the tongue to its extremity there is a groove, which divides it, according to its length, into two equal parts. This groove is a real channel, furnished with a great number of small muscles, that open and shut it: in this channel is contained a viscous liquor, which is the matter of the threads emitted by the muscle. At its first appearance this channel is exactly cylindrical, and is, properly speaking, the place where the threads are moulded. The various motions the tongue of the muscle, we are observing, gave itself a minute ago, all tended to fix it to the stone: those threads which are the whitest and most transparent, are such as are newly spun. She has not yet finished anchoring herself, wherefore you perceive her tongue is again extending about two inches, and the tip of it drawing towards the stone: the viscous liquor runs in the channel, and arrives at the extremity of it. This liquor is now consolidated, and becomes a cylindrical thread. The muscle sticks the end of his thread to the stone; but is desirous of applying it by a wider surface, in order to render it more adherent: for that purpose, she adds to it, with the tip of her tongue, that little paste which you observed. Her business now is to extend another cable to some distance from the last: the tongue, therefore, must quit this latter in order to work elsewhere. How will she be able to effect this? The channel opens itself to its utmost length, and discharges the thread. The tongue being disengaged from his thread, quickly draws itself together, re-enters the shell, and the next moment again issues from it, to fix a new cable a little farther off.

Did you take notice of a mark of skill expressed by our muscle? She has just now spread the first thread; to assure herself of the goodness of it, she immediately puts it to the proof; drawing it strongly towards her, as though she would break it. It has resisted this effort; and, satisfied with the experiment, she has proceeded to stretch out the second thread, which she has tried like the first.

These cords, which the sea-muscles spin with so much art, are, in reality, as serviceable to them as cables are to a ship. You ask me, whether they can weigh anchor? Divers experiments prove they are not endued with that ingenuity. It was not necessary for them. But they sometimes drive with their anchors; it therefore behoves them to have fresh cables in reserve.

Thus the sea has its spinners as well as the earth. Muscles are at sea the same that caterpillars are on land. There is, nevertheless, a remarkable difference between them. The work of caterpillars answers exactly to that of gold wire-drawers. The silk thread is moulded by passing through the mouth of the spinner, and the caterpillar gives it what length she pleases; which, in certain cones, consists of several hundred feet. The labour of muscles may rather be compared to that of workmen who cast metals. The spinning instrument of these shell-fish is a real mould, which does not only determine the thickness of the thread, but also its length, which is always equal to that of the spinning instrument, or tongue.

The *pinnæ marinæ*, which are species of very large muscles, are more dextrous spinners still. Their threads, which are at least seven or eight inches long, are extremely fine, and curious works are made with them. If muscles are caterpillers of the sea, pinnæ are its spiders. The threads of the pinnæ serve, like those of muscles, to moor them with, and defend them from the agitation of the waves. They are prodigiously numerous, and being united, form a kind of tuft or skain, weighing about three ounces. The instrument that prepares and moulds them, resembles, in the essential properties of it, that of other shell-fish of this kind; except that it is much larger, and the groove that divides it lengthwise is much narrower. At the root of it there is a membranous bag, composed of several fleshy layers, that separate the silk layers from whence the tuft results.

24. If all kinds of shell-fish and sea-animals have not been enabled to moor themselves with as much skill as muscles and pinnæ, nature has made them amends for that by affording them means that are no less efficacious. Before we quit this shore, let us stop a little while and examine this small shell-fish which you see fastened to this rock: it is a *goat's eye,* or a *limpet.* Its shell, which consists of one piece only, is made like a conic chapiter, under which the whole body is sheltered, as under a roof: the animal can raise or lower this covering as it pleases. When it lowers it the body is entirely concealed, and it rests immediately on the stone. A large muscle that occupies the whole extent of the shell, and that is, as it were, the base of it, fastens the animal to this stone. Try to disengage it from it; you are not able to effect it. It is, nevertheless, only fixed to the stone by a base of an inch and a half in diameter. Let us hoist a cord round the shell, and suspend a weight of twenty-eight or thirty pounds to this cord, the shell-fish will not quit its hold till after some seconds; and you are surprised that so small an animal should be endued with so great a power of adhesion. You are curious to know from whence he derives this: you examine the stone, and it appears to you to be finely polished, whereupon, your astonishment is redoubled. Can it be that the muscle is able to insinuate itself into the insensible parts of the

stone? Divide the animal transversely, it still adheres as strongly as before. Does it cleave to the stone as two pieces of polished marble cleave to each other? But pieces of marble easily slip each other; and you cannot cause the shell-fish so to do. This, then, is the secret cause of that adhesion which astonishes you. The muscle is furnished with a viscous humour, which agglutinates it to the surface of the stone, and which is sensibly felt by touching it with the finger.

But the goat's eye has not been condemned to remain its whole life affixed to the same place: it is necessary for it to go in search of its food. There is one now creeping on the rock: its great muscle serves him instead of legs, and performs the same functions as that you have been made acquainted with in the snail. The goat's eye, then, can disengage himself when he pleases: it is able to break those strings which are with difficulty disjointed by a weight of eight-and-twenty pounds. Moisten your finger, and stroke the muscle with it; the natural glutinous substance with which it is endued, can no longer retain its hold. This glue is dissoluble by water. The whole surface of the muscle abounds with little seeds, filled with a dissolvent liquor. When the animal is disposed to shift his quarters, he need only press his numerous glands, the dissolvent issues from them, and the cords are broken. The goat's eye has but one certain provision of gluy matter. If it be loosened from its place several times together, its stock will be exhausted, and it will not fix any more.

This method of mooring is common to divers sea-animals. It is particularly so to *nettles*. Its whole skin is one entire mass of glue, which dissolves very speedily in aqua vitæ. It is with this abundant glue that these extraordinary animals fasten themselves to the rocks.

Star-fishes also fix themselves by the same method.

A viscous matter is conducted to the extremity of the horns that serve them instead of legs. These legs become strong ties to them by means of the glue that exsudes from them, and when they are once fastened, it is easier to break than separate them. The horns of hedgehogs are exactly of the same nature.

All these adhesions are voluntary, and depend solely on the good pleasure of the animal. He joins or disjoins himself as circumstances require. But there are other adhesions, which are altogether involuntary. Sea-worms, that are called *pipe* worms, are enclosed in a round tube of a substance resembling that of shells, and fastened to stones or hard sand, or even to other shell-fish. This tube follows the turnings of the surface to which it is fixed: the worm never quits this shell, which he lengthens or widens as he grows. They recal to your remembrance the false moths: this may be termed a *false moth* of the sea. It emits from its whole body a stony juice, which is the matter whereof the tube is formed.

Other worms of this species, whose juice is not of a stony nature, but glutinous, make use of it for collecting round them grains of sand, or bits of shells, and this shell of inlaid pieces is notwithstanding wrought in pretty exact proportion.

Oysters, and many other shell-fish, adhere by a stony liquor to the bodies whereon they rest, and are often by this means cemented to one another. Of such a species is that universal cement which nature makes use of, as often as she would erect in the sea, or establish therein a shell-work against the violent motion of the waves.

We have acquired but little knowledge of the industry of fishes. They are not sufficiently within our reach. The greatest part of them inhabit gulphs that are inaccessible to our researches. We do not presume to think, that all their intelligence is confined solely to the devouring of each other. Their migrations are also as remarkable as those of bird. They may have need of a kind of genius to enable them to chase their prey with success, and elude the pursuit of their enemies. The *cuttle-fish* scatters about, at a proper season, a black liquor, which troubles the water, and hides her from the sight of such fishes as attempt to take away her life. Perhaps this liquor may be serviceable to her in seizing, with the greater ease, those she feeds upon. Other fishes can, with abundance of art, penetrate into very hard shells, and extract from thence the fleshy substance contained in them. We are not yet acquainted with the use the *sword-fish*, the *saw-fish*, and the *narval*, or *unicorn-fish*, make of those enormous instruments they wear at the end of their snouts; but they are undoubtedly able to handle them. Has not the *cramp-fish*, which so suddenly benumbs the hand that touches it, a very remarkable method of providing for its safety, and an excellent art to propose to the meditation of the natural philosopher? The *flying-fish*, when pursured by others, darts out of the watry element to take refuge in the air, where it is for a time sustained by its great fins.

It is well known that carp are capable of being tamed, and that they will hasten, like fowls, at a certain signal, to receive food from the hands of their provider.

It is probable that fishes are of all other animals endued with the longest lives. We have seen carp of an hundred and fifty years old. Fishes transpire and harden but little; they have, properly speaking, no bones: but they live in a state of perpetual warfare: they all devour, or are devoured by others. Those who attain to their age, must acquire an extensive knowledge of things relating to the sea. Such Nestors as these may be able to procure us some good memoirs of the secret history of a people so little known.

25. We conjecture that the emigrations of birds de-

pends principally on the winds. An exact naturalist at Malta has assured himself of this, that the same species always change their climate with particular winds. In April the *south-west* wind brings into that island a species of *plovers*, and the *north-west*, *cardinals*, and *quails*. Nearly at the same time, *falcons*, *buzzards*, and other birds of *prey*, come with the *north-west* wind, without stopping, and depart in October with the *south* and *west*. In summer the *easterly* wind conducts the snipes to Malta, and, towards the autumn, the *north* and *north-west* bring thither numerous squadrons of *woodcocks*. These birds cannot fly, like the *quails*, before the winds, since the *north* wind, which might carry them into Barbary, obliges them to remain in the isles. *Quails*, on the contrary, emigrate before the *wind* from one country to another. The *south-east* enables them to pass, in the month of March, from Barbary into France. They return from France in September, and go to Malta by a *south-east*. The winds, therefore, are the signals employed by nature for reminding divers kinds of birds of the time of their departure. In obedience to this voice, they set out, and follow the direction it points out to them.

What a series of interesting circumstances would not the construction of their nests also present us with! A chaffinch or goldfinch's nest would take us up whole hours in contemplating it. We should enquire where the goldfinch could furnish itself with a cotton so fine, silky, and soft, as lines the inside of its pretty nest? After many researches we should find that, by covering the seeds of certain willows with a very fine cotton, nature has prepared for the goldfinch the down she employs. We should never be weary of considering that kind of embroidery with which the chaffinch so agreeably adorns the outside of his nest, and, on viewing it more narrowly, we should perceive that it is owing to an infinity of little liverworts, artfully interwoven together, and applied with the utmost propriety over the whole surface of the nest. The colour of these liverworts, which is most commonly that of the bark of the tree on which the nest is situate, would indicate that the chaffinch seems to intend her nest should be confounded with the branch that bears it.

26. Shall we visit the retreats of *rats, field-mice, badgers, foxes, otters, bears.* We should undertake thereby too tedious a journey. Let us limit ourselves to the *rabbit* and *monkey,* as the most curious after those of the beaver.

The *rabbit* and *hare,* which bear so near a resemblance to each other, both in their exterior and interior part, teach us not to trust to appearances: they easily couple together, and produce nothing: they are, therefore, distinct species.

Moreover, the feeble hare contents herself with the lodging she makes for herself on the surface of the earth. The more industrious rabbit penetrates into the earth, and there procures an assured asylum. The male and female live together in this peaceable retreat, fearless of the fox or bird of prey. Unknown to the rest of the world, they spend their days in happiness and tranquillity.

The hare might also dig the earth, but does not, neither does the domestic rabbit, since he has no occasion; his dwelling-place being provided for him, he behaves as if he was sensible of it. The warren-rabbit seems to know that he is unprovided, and procures for himself a lodging. But to perceive the relations those retreats have to their preservation, and to judge that they will shelter them from all the inconveniences they labour under, is an operation of the soul that borders on *reflection,* if it be not reflection itself.

When the hare is ready to kindle, she digs for herself a burrow. This is a winding trench, or one made in zig-zag. At the bottom of this trench she works a great cavity, lining it with her own hairs: that is the soft bed she prepares for her young. She does not quit them during several of the first days; and only goes out afterwards to procure nourishment. The father at that time knows nothing of his family; he does not dare to enter the burrow. When the mother goes into the fields, she often takes even the precaution to stop up the entrance of the burrow with earth steeped in her urine. When they are grown somewhat larger, the leverets begin to brouse the tender grass. The father at that time acquires a knowledge of them, takes them up in his paws, licks their eyes, polishes their hair, and distributes his caresses and cares equally amongst them all.

Observations prove that paternity is greatly respected amongst hares. The grandsire continues to be the chief of the whole numerous family, and seems to govern it like a patriarch.

27. The tricks of the *monkey* are known to every body: no one is ignorant with what facility she is tamed, and taught to dance and shew postures on a staff. Her ingenious proceedings on the tops of the Alps, where she fixes her abode, in the midst of snow and frost, are not so generally known.

Towards the month of October she enters into winter-quarters, and shuts herself up for the remainder of the season: her retreat is worthy of observation. On the brow of a mountain the industrious monkey establishes her dwelling. It is a great gallery dug underground, and made like a Y. These two branches, which have each of them an opening, terminate at a *corner*. Such is the apartment of the monkey. One of the branches descends below the apartment, according to the sloping of the mountain; it is a kind of aqueduct that receives and carries off the excrements and filth. The other branch, which rises above the habitation, serves for an avenue and place to go out at. The apartment is the only part of the gallery which is horizontal. It is lined with a thick layer of moss and hay. It is certain that monkeys are sociable animals, and that they work in common on their lodging. They amass, during the summer, ample supplies of moss and hay. Some mow the grass, others gather it, and by turns they supply the office of a cart to convey it to the storehouse. One of the monkeys lies on his back, opens his paws to serve instead of *racks*, suffers himself to be loaded with hay, and drawn by the rest, who hold him by the tail, and are careful to prevent the carriage being overturned on the road. Their feet are armed with claws, which enable them with great ease to dig into the earth. As soon as they have made a hollow place in it, they throw behind them the dirt they extract from the mine. They pass the greatest part of their life in their habitation; they retire into it during the rain, or on the approach of a storm, or at the sight of some imminent danger. They seldom quit it except in fine weather, and go but a little way from it. Whilst some are sporting on the turf, others are busy in cutting it, and a third party are acting as scouts on the eminences, to give notice to the foragers, by a whistle, of the enemy's approach.

During the winter monkeys eat nothing: the cold benumbs them, suspends, or greatly diminishes perspiration, and other excretions. The fat, with which their belly is well provided, passes into the blood and restores it. We might affirm that they foresee their lethargy, and are apprized that they shall then have no need of nourishment; for they do not think of hoarding up provisions, as they do materials for furnishing their lodging.

28. We have greatly admired the ingenious and almost intelligent mechanism by which divers caterpillars roll up the leaves of trees. You see these ash-leaves that are rolled up like a coffin. They are inhabited by a little caterpillar, that has formed for itself therein a cone of pure silk, nearly resembling a grain of corn. We cannot examine this cone without opening the coffin; let us do it with caution. The cone is lodged it the centre: you perceive little gutters on the exterior part of it. Observe particularly in what manner this little cone is suspended in the middle of the coffin, by the help of a thread, one of whose extremities is

fixed to the top of the cone, and the other to its base, or the flat part of the leaf. Look narrowly at the place where the thread joins to the flat part of the leaf: you will perceive a small piece in it exactly circular, bored in the thick part of the leaf, and that seems to conceal some secret design. This you will find in many coffins; but it often happens that you will see in that place a little round hole, well turned, that appears to have been made by a *gimblet.* The circular piece is the work of the caterpillar, it has skilfully gnawed that part of the leaf; and has cut a little piece of it in a circular form, which it has been very careful to leave in its place. You seem to discern the end of this labour. It is contrived for a private passage for the caterpillar to go out at, at the same time that it prevents the entrance of any mischievous insects. Our industrious caterpillar then makes a little door into its cell: the door is not to be opened till after the last metamorphosis. The winding parts of it being interwoven with the leaf, it remains as it were subservient to it. In issuing from the cone the caterpillar descends by the whole length of the thread, which holds it suspended; it follows the direction of it, arrives at the door, and bursts it open by pushing its head against it. These coffins, which you see pierced through, have been abandoned by the caterpillars.

29. Our grain is liable to be eaten by a very small insect, that lodges within it, and is there metamorphosed. The covering of corn is a kind of very close box, which the caterpillar lines with silk. But the caterpillar is provided with no instrument to pierce through this box, and would remain prisoner therein, if the insect were not instructed how to prepare a passage from it. It proceeds in the same manner as the roller of the ash; it cuts with its teeth a little round place in the covering of the grain, which it is very careful not to disengage entirely from it. The butterfly need only press against this part, in order to obtain its liberty.

In the centre of the *capper* thistle there is a large oblong cavity, which is commonly inhabited by a small caterpillar, that makes a sort of cone therein, where she transforms herself. The rind of the thistle is much harder than that of our corn: it would be impossible for the butterfly to force a passage through it. It would have occasion for very strong teeth for that purpose, and is furnished with no analogous instruments. The caterpillar, which seems sensible of this, makes a skilful provision for the necessities of the butterfly. It pierces in different parts the walls of its lodge, and makes a small round hole in it, opposite the extreme part of the cone which the butterfly is to go out at; but, where this hole to remain open, the chrysalis would be too much exposed. The caterpillar contrives a very simple expedient for stopping up the aperture. The whole exterior part of the head of the thistle is covered with the seeds of the plant. The caterpillar brings some of these little bodies to the outside of the hole.

In treating of the proceedings of *aquatic* moths, we have remarked that they transform themselves in their case. There must be a continual fresh supply of water in this enclosure: yet, no voracious insect should be allowed access to it. Instead of placing a full made door at the entrance of its lodge, the moth puts a grated one there, which answers every end. Let us not attribute our method of reasoning to this moth. Does she know that voracious insects have a design against her life? Is she sensible that she will put on a form under which she will not be able to fly? No; she is ignorant of all this; nor does it concern her to know it. She has been taught to spread threads that are capable of growth; she does spread them, in so doing, she provides by a machine against the inconveniencies which she neither knows or can know. Judge on the same principle of other facts of this kind. It is always the AUTHOR of the insect who alone is to be esteemed wonderful.

30. I need not then endeavour, from the end which we discover in the work of an industrious animal, to find a reason for this work. I would not say, *The spider spreads a net to catch the flies*; but that *the spider catches the flies because she spreads a net, &c.* and she forms a net, because she has *occasion to spin.* The end is not less certain, or less evident; only, it is not the animal that has proposed it, but the AUTHOR of the animal. What loss would natural theology sustain by this method of reasoning? Would it not, on the contrary, acquire a greater degree of exactness? Let us reason then on the operations of animals as we do on their structure. The same WISDOM which has constructed and arranged with so much art their various organs, and has caused them to concur to one determinate end, has likewise caused those numerous operations, which are the natural effects of the economy of the animal to contribute to one end. He is directed towards his end by an invisible HAND; he executes with precision, from the very beginning, the works which we admire; he seems to act as if he was capable of reasoning, to turn about with propriety, and to change his method as there is occasion, and in all this only obeys those secret springs by which he is actuated; he is only a blind instrument that cannot judge of his own action, but is excited to it by that ADORABLE MIND which has traced out to every insect his little circle, as he has marked out to each planet its proper orbit. When, therefore, I see an insect working on the construction of a net, a cone or a chrysalis, I am seized with respect, because I am beholding a sight where the SUPREME ARTIST is concealed behind the scene.

31. Many species of solitary bees content themselves with penetrating into the earth; scoop out cylindrical cavities therein, and polish the walls. They deposit an egg there, and amass a sufficient quantity of nourishment.

There is another species of these worms that pierce the earth, whose industry is much more remarkable. They do not content themselves, like the others, with an entire naked cavity. On visiting the inside of the lodge, immediately after its construction, we are agreeably surprised to see it hung quite round with tapestry, of the most beautiful crimson satin, affixed to the sides, as our tapestry is to the walls of our apartments, but with much more propriety. The bee does not only line in this manner the whole inside of her dwelling; but also spreads the same kind of tapestry round the entrance, to the distance of two or three lines. We have observed many caterpillars that line the inside of their cone or inclosure with silk: our bee is the only insect at present known which, properly speaking, hangs her nest with tapestry, as we do our apartments. It is, therefore, with good reason that this industrious animal has received the name of the tapestry-bee.

You seem at a loss to know from whence she procures the rich tapestry. Look at the flowers of this wild-poppy, which are newly blown; observe that they are sloped here and there. Compare them with the tapestry whose tissue you are desirous of knowing; you can find no difference between them: this tapestry is no other than the fragments of the flowers of the wild-poppy; and that is the secret origin of those slopings you remark on the poppies that border upon the nest. Your curiosity is not yet satisfied; you are desirous of observing a little the labour of our skilful worker in tapestry.

The hole which she digs perpendicularly into the earth, is about three inches in depth: it is exactly cylindrical, as far as to seven or eight lines of the bottom. There it begins to open wider, which it does more and more. When the bee has made an end of giving it the suitable proportions, she proceeds to line it with the tapestry.

With this view, she applies herself to cutting, with abundance of art, pieces of petals,* of an oval form,

* This is the name given by botanists to the leaves of flowers.

from the flowers of the wild-poppy, which she seizes with her legs, and conveys into her hole. These little scraps of tapestry, when transported thither, are very much crumbled; but the *tapestry-bee* knows how to spread them out, display them, and affix them to the walls with astonishing art.

She applies at least two layers of the petals. She spreads two tapestries on each other. The reason of her furnishing herself with it from the flowers of the wild-poppy, rather than from those of many other plants, is, because in them are united, to a higher degree, all those qualities which are requisite for the use to which the bee designs to put them.

When the pieces which the bee has cut and transported, are found to be too large for the place they are intended to occupy, she cuts off the superfluous parts of them, and conveys the *shreds* out of the apartment.

After hanging the tapestry, the bee fills the nest with *paste*, to the height of seven or eight lines: this is all that is necessary for the nourishment of the worm. The tapestry is designed to prevent the mixture of particles of earth with the paste.

You expect, undoubtedly, that the prudent bee should not fail to close up effectually the aperture of the nest, in order to hinder the access of those insects into it that are fond of the paste; this she takes proper care to do: and it is utterly impossible for you to discover, from the surface of the ground, the spot where the nest was, whose construction you have just been contemplating, such is the skill employed by the bee in closing it. This little white pebble was at the edge of the hole, or very near it; it has not changed its place, and indicates to us the part beneath which the nest is we are searching for. It seems then as if we should have nothing more to do than to raise up a light layer of earth, in order to expose to view the entrance of the hole, which has been so well closed. Nothing can be easier or less doubtful. How great is your surprise! you have already taken up two or three inches of the earth in depth, and you cannot find the least appearance either of the hole or the tapestry. What can this mean? What is become of the nest that was so skilfully constructed, so properly lined, and was upwards of three inches deep? A few hours since, you admired the ingenious contrivance of it, and now the whole has disappeared, so that you cannot discover the least trace of it. What mystery then is this? It is effected as follows:

When the bee has done laying, and amassed her quantity of paste, she takes down the tapestry, folds it over the paste, which she wraps together in it, pretty nearly as we fold on itself a coffin of paper that is half full: the egg and paste are by this means inclosed within a little bag of flowers. The bee has then nothing farther to do, but to fill up with earth all the void space that is above the bag; and this she performs with such wonderful activity and exactness, as utterly to conceal the place where the nest was.

If a hare does not possess, like the rabbit, the art of digging for himself a burrow, he does not, however, want a sufficient degree of sagacity to enable him to secure himself, and escape from his enemies. He can choose for himself a form, and conceal himself betwixt clods of earth that resemble the colour of his hair. In winter, he takes up his lodging to the south, and in summer time to the north; when started by the dogs, he pursues the same track for some time, goes the same way back again, darts aside, throws himself into a bush, and there squats down. The pack follow the path, pass before the hare, and lose scent of him.

The crafty animal sees them pass by and run far from him, he issues from his retreat, confounds his course, and puts the hounds to a loss. He varies his shifts continually, and always conducts them as his circumstances require. Sometimes at the cry of the hounds, he quits his form, speeds away to the distance of a quarter of a league, casts himself into a pond, and lies hid among the rushes. At others, he mingles with a flock of sheep, and will not abandon them. One time he conceals himself under ground: at another leaps under a ruinous wall, crouches among the ivy, and lets the dogs pass him. Oftentimes he runs along one side of a hedge, whilst the dogs go on the other. Sometimes, by several efforts, he swims across a river. Lastly, at others, he obliges another hare to quit the form, in order to supply his place, &c.

The stag, which by the elegance and lightness of his make, by those living *branches* with which his head is rather adorned than armed, his size, strength, and noble air, is one of the grand ornaments of the forest, is endued with more subtlety than even the hare, and finds more exercise for the sagacity of the huntsman.

When pursued by the hounds, he passes and re-passes several times on his track; eludes their pursuit by assorting himself with other beasts, darts forward, and immediately flees to a distance; starts aside, and steals away, and lies prostrate on his belly. The land betraying him every where, he betakes himself to the water. The hind, that nourishes her young, presents herself to the dogs, in order to facilitate the escape of her young; she runs away with swiftness, and afterwards returns to it.

32. The fox, celebrated for his subtlety, is no less circumspect than skilful, no less vigilant than crafty; he weighs cautiously the least of his measures, studies circumstances, watches incessantly, and has always some contrivance in reserve to assist him upon an exigency. His genius, so fruitful in resources, multiplies almost to infinity his shifts and stratagems.

Though extremely fleet in running, he does not trust to his natural swiftness: he judges that that alone would not be sufficient for his preservation. He works for himself a timely asylum under ground; where he takes refuge in case of necessity, and lodges, and brings up his family.

He establishes his dwelling-place on the border of woods, and in the neighbourhood of farm-houses. He listens afar off, with an attentive ear, to the cackling of poultry, directs his steps accordingly, arrives by several winding ways, squats himself down, passes along on his belly, lies in ambuscade, and rarely fails in his attempt.

If he is so happy as to penetrate into the inclosure, he employs to good purpose every moment of his time, and slaughters the whole stock. He immediately retreats, carries away with him one of the prey, conceals it, returns in search of another, hides that like the former, and does not cease from plundering, till he perceives he has been discovered.

He is amazingly skilful in hunting young leverets, surprising the hares when laying down, in discovering the nest, of partridges, or quails, and seizing the mother on her eggs.

Equally bold as crafty, he has even the courage to attack bees: he attempts to get their honey, which he is very fond of. These warlike insects presently assail him on all sides, and in a few moments he is entirely covered with them. He retires some paces, rolls himself on the ground, crushes them by that means, returns to the charge, and at length obliges this little laborious people to abandon to him the fruits of their long labours.

I shall add but one more instance: if the fox discovers that his young have been disturbed during his absence, he transports them, one after another, to a new place of retreat.

CONCLUSION.

HERE I set bounds to my design. I have presented my readers with a variety of facts of an interesting nature, sufficient to enable them to form an idea of those pleasures which result from the contemplation of nature. But this contemplation would prove fruitless, did it not lead us to aspire incessantly after this adorable BEING, by endeavouring to acquire a knowledge of him, from that immense chain of various productions wherein his power and wisdom are displayed with such distinguished lustre. He does not impart to us the knowledge of himself immediately; that is not the plan he has chosen; but he has commanded the heavens and the earth to proclaim his existence, to make him known to us. He has endued us with faculties susceptible of this divine language, and has raised up men who explore their beauties, and become their interpreters. Imprisoned for awhile in a small obscure planet, we only enjoy such a portion of light as is suitable to our present condition: let us wisely improve each glimmering ray reflected upon us, nor lose the smallest spark: let us continually advance in this Effulgent Light! A time will come, when we shall draw all light from the Eternal Source of Light, and instead of contemplating the Divine Architect in the works of his hands, shall contemplate the workmanship in the OMNIPOTENT AUTHOR thereof. "We now see things as through a glass darkly; but we shall then see face to face."

END OF THE FOURTH VOLUME.

Printed by J. D. Dewick, 46, Barbican.