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A SYSTEM

OF

SYNTHETIC PHILOSOPHY.

VOL. II

THE PRINCIPLES

OF

BIOLOGY.

BY

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VOL. I.

NEW YORK:
D. APPLETON AND COMPANY,
1, 3, AND 5 BOND STREET.
1891.

PREFACE TO THE AMERICAN EDITION.

The *System of Philosophy* now in course of publication by Mr. Herbert Spencer begins with a volume of *First Principles*, which was republished in this country a year or two since. The subject of *Biology* comes next in order, and is to be treated in two volumes, of which the present is the first; Volume II. will probably appear toward the close of the year. In accordance with the author's plan, the doctrine or method of Evolution unfolded in *First Principles* and applied to Biology in the present work, will be carried out in the subsequent treatment of the *Principles of Psychology* and the *Principles of Sociology*.

In the preface to the English edition, Mr. Spencer remarks:

"The aim of this work is to set forth the general truths of Biology, as illustrative of, and as interpreted by, the laws of Evolution: the special truths being introduced only so far as is needful for elucidation of the general truths.

"For aid in executing it, I owe many thanks to Prof. Huxley and Dr. Hooker. They have supplied me with information where my own was deficient; and in looking through the proof-sheets, have pointed out errors of detail into which I had fallen. By having kindly rendered me this valuable assistance, they must not, however, be held committed to any of the enunciated doctrines that are not among the recognized truths of Biology."

New York, *March*, 1866.

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PART I.

THE DATA OF BIOLOGY

CHAPTER I.

ORGANIC MATTER.

§ 1. Of the four chief elements which, in various combinations, make up living bodies, three are gaseous. While carbon is known only as a solid, oxygen, hydrogen, and nitrogen habitually maintain the aeriform state. Only by intense pressures joined with extreme refrigerations have two out of the three (some say all) been reduced to the liquid form. There is a certain significance in this. When we remember how those re-distributions of Matter and Motion which constitute Evolution, structural and functional, imply motions in the units that are re-distributed; we shall see a probable meaning in the fact that organic bodies, which exhibit the phenomena of Evolution in so high a degree, are mainly composed of ultimate units having extreme mobility. The properties of substances, though destroyed to sense by combination, are not destroyed in reality: it follows from the persistence of force, that the properties of a compound are *resultants* of the properties of its components—*resultants* in which the properties of the components are severally in full action, though greatly obscured by each other. One of the leading properties of each substance is its degree of molecular mobility; and its degree of molecular mobility more or less sensibly affects the molecular mobilities of the various compounds into which it enters. Hence we may infer some relation between the gaseous form of three out of the four chief organic elements, and that comparative readiness displayed by organic matters to undergo those changes in the arrangement of parts which we call development, and those transformations of motion which we call function.

Considering them chemically instead of physically, it is to be remarked that three out of these four main components of organic matter, have affinities which are narrow in their range and low in their intensity. Hydrogen combines with comparatively few other elements; and such chemical energy as it does show, is scarcely at all shown within the limits of the organic temperatures. Of carbon it may similarly be said that it is totally inert at ordinary heats; that the number of substances with which it unites is not great; and that in most cases its tendency to unite with them is but feeble. Lastly, this chemical indifference is shown in the highest degree by nitrogen—an element which, as we shall hereafter see, plays the leading part in organic changes.

Among the organic elements, including under the title not only the four chief ones, but also the less conspicuous remainder, that capability of assuming different states, called allotropism, is frequent. Carbon presents itself in the three unlike conditions of diamond, graphite, and charcoal. Under certain circumstances, oxygen takes on the form in which it is called ozone. Sulphur and phosphorus (both, in small proportions, essential constituents of organic matter) have allotropic modifications. Silicon, too, is allotropic; while its oxide, silica, which is an indispensable constituent of many lower organisms, exhibits the analogue of allotropism—isomerism. And even of the iron which plays an active part in higher organisms, and a passive part in some lower ones, it may be said that though not known to be itself allotropic, yet isomerism characterizes those compounds of it that are found in living bodies. Allotropism being interpretable as some change of molecular arrangement, this frequency of its occurrence among the components of organic matter, is significant as implying a further kind of molecular mobility.

One more fact, that is here of great interest for us, must be set down. These four elements of which organisms are almost wholly composed, present us with certain extreme antitheses. While between two of them we have an unsurpassed contrast in chemical activity; between one of them and the other three, we have an unsurpassed contrast in molecular mobility. While carbon, by successfully resisting fusion and volatilization at the highest temperatures that can be produced, shows us a degree of atomic cohesion greater than that of any other known element, hydrogen, oxygen, and nitrogen, show the least atomic cohesion of all elements. And while oxygen displays, alike in the range and intensity of its affinities, a chemical energy exceeding that of any other substance (unless fluorine be considered an exception), nitrogen displays the greatest chemical inactivity. Now on calling to mind one of the general truths arrived at when analyzing the process of Evolution, the probable significance of this double difference will be seen. It was shown (*First Principles*, § 123) that, other things equal, unlike units are more easily separated by incident forces than like units are—that an incident force falling on units that are but little dissimilar does not readily segregate them; but that it readily segregates them if they are widely dissimilar. Thus, these two extreme contrasts, the one between physical mobilities, and the other between chemical activities, fulfil, in the highest degree, a certain further condition to facility of differentiation and integration.

§ 2. Among the binary combinations of these four chief organic elements, we find a molecular mobility much less than that of these elements themselves; at the same time that it is much greater than that of binary compounds in general. Of the two products formed by the union of oxygen with carbon, the first, called carbonic oxide, which contains one atom of carbon to one of oxygen (expressed by the symbol C O), is an incondensible gas; and the second carbonic acid, containing an additional atom of oxygen ($C\,O_2$) assumes a liquid form only under a pressure of nearly forty atmospheres. The several compounds of oxygen with nitrogen, present us with an instructive gradation. Protoxide of nitrogen, which contains one atom of each element (N O), is a gas condensible only under a pressure of some fifty atmospheres; deutoxide of nitrogen ($N\,O_2$) is a gas hitherto uncondensed (the molecular mobility remaining undiminished in consequence of the volume of the united gases remaining unchanged); nitrous acid ($N\,O_3$) is gaseous at ordinary temperatures, but condenses into a very volatile liquid at the zero of Fahrenheit; peroxide of nitrogen ($N\,O_4$) is gaseous at 71°, liquid between that and 16°, and becomes solid at a temperature below this; while nitric acid ($N\,O_5$) may be obtained in crystals which melt at 85° and boil at 113°. In this series we see, though not with complete uniformity, a decrease of molecular mobility as the weights of the compound molecules are increased. The hydro-carbons illustrate the same general truth still better. One series of them will suffice. Marsh gas ($C_2\,H_4$) is permanently gaseous. Olefiant gas ($C_4\,H_4$) may be liquefied by pressure. Oil gas, which is identical with olefiant gas in the proportions of its constituents but has double the atomic weight, ($C_8\,H_8$), becomes liquid without pressure at the zero of Fahrenheit. Amylene ($C_{10}H_{10}$) is a liquid which boils to 102°. And the successively higher multiples, caproylene ($C_{12}\,H_{12}$), caprylene ($C_{16}\,H_{16}$), elaene ($C_{18}\,H_{18}$) and paramylene ($C_{20}\,H_{20}$), are liquids which boil respectively at 102°, 131°, 257°, 230°, and 329°. Cetylene ($C_{32}\,H_{32}$) is a liquid which boils at 527°; while paraffine ($C_{40}\,H_{40}$) and mylene ($C_{60}\,H_{60}$) are solids. Only one compound of hydrogen with nitrogen has been obtained in a free state—ammonia ($H_3\,N$); and this, which is gaseous, is liquefiable by pressure, or by reducing its temperature to —40° F. In cyanogen, which is composed of nitrogen and carbon ($N\,C_2$), we have a gas that becomes liquid at a pressure of four atmospheres and solid at —30° F. And, in paracyanogen, formed of the same proportions of these elements in higher multiples (N_3 C_6), we have a solid which does not fuse or volatilize at ordinary temperatures. Lastly, in the most important member of this group, water, (H O or else as many chemists now think H_2 O_2) we have a compound of two incondensible gases which assumes both the fluid state and the solid state within ordinary ranges of temperature; while its molecular mobility is still such that its fluid or solid masses are continually passing into the form of vapour, though not with great rapidity until the temperature is raised to 212°.*

Considering them chemically, it is to be remarked of these binary compounds of the four chief organic elements, that they are, on the average, less stable than binary compounds in general. Water, carbonic oxide, and carbonic acid, are, it is true, difficult to decompose. But omitting these, the usual strength of union among the elements of the above-named substances is low considering the simplicity

* This immense loss of molecular mobility which oxygen and hydrogen undergo on uniting to form water—a loss far greater than that seen in other binary compounds of analogous composition—suggests the conclusion that the atom of water is a multiple atom. Thinking that if this conclusion be true, some evidence of the fact must be afforded by the heat-absorbing power of aqueous vapour, I lately put the question to Prof. Tyndall, whether it resulted from his experiments that the vapour of water absorbs more heat than the supposed simplicity of its atom would lead him to expect. I learned from him that it *has* an excessive absorbent power—an absorbent power more like that of the complex-atomed vapours than like that of the simple-atomed vapours—an absorbent power that therefore harmonizes with the supposition that its atom is a multiple one. Besides this anomalous loss of molecular mobility and this anomalous heat-absorbing power, there are other facts which countenance the supposition. The unparalleled evolution of heat during the combination of oxygen and hydrogen is one. Another is that exceptional property which water possesses, of beginning to expand when its temperature is lowered below 40°; since this exceptional property is explicable only on the assumption of some change of molecular arrangement—a change which is comprehensible if the molecules are multiple ones. And yet a further confirmatory fact is the ability of water to assume a colloid condition; for as this implies a capacity in its atoms for aggregating into high multiples, it suggests, by analogy with known cases, that they have a capacity for aggregating into lower multiples.

of the substances. With the exception of acetylene, the various hydro-carbons are not producible by directly combining their elements; and the elements of most of them are readily separated by heat without the aid of any antagonistic affinity. Nitrogen and hydrogen do not unite with each other immediately; and the ammonia which results from their mediate union, though it resists heat, yields to the electric spark. Cyanogen is stable: not being resolved into its components at a red heat, unless in iron vessels. Much less stable however are the several oxides of nitrogen. The protoxide, it is true, does not yield up its elements below a red heat; but nitrous acid cannot exist if water be added to it; hypo-nitric acid is decomposed both by water and by contact with the various bases; and nitric acid not only readily parts with its oxygen to many metals, but when anhydrous, spontaneously decomposes. Here it will be well to note, as having a bearing on what is to follow, how characteristic of most nitrogenous compounds is this special instability. In all the familiar cases of sudden and violent decomposition, the change is due to the presence of nitrogen. The explosion of gunpowder results from the readiness with which the nitrogen contained in the nitrate of potash, yields up the oxygen combined with it. The explosion of gun-cotton, which also contains nitric acid, is a substantially parallel phenomenon. The various fulminating salts are all formed by the union with metals, of a certain nitrogenous acid called fulminic acid; which is so unstable that it cannot be obtained in a separate state. Explosiveness is a property of nitro-mannite, and also of nitro-glycerin. Iodide of nitrogen detonates on the slightest touch, and often without any assignable cause. Percussion produces detonation in sulphide of nitrogen. And the body which explodes with the most tremendous violence of any that is known, is the chloride of nitrogen. Thus these easy and rapid decompositions, due to the chemical indifference of nitrogen, are characteristic. When we come hereafter to observe the part which nitrogen

The like is still more conspicuous in other groups of the hydro-carbons, as in the essential oils: sixteen to twenty of which are severally isomeric with essential oil of turpentine. Here the particular kind of molecular mobility implied by these metamorphoses, is well shown: essential oil of turpentine being converted into a mixture of several of these polymerides, by simple exposure to a heat of 460°.

There is one further fact respecting these binary compounds of the four chief organic elements, which must not be overlooked. Those of them which form parts of the living tissues of plants and animals (excluding water which has a mechanical function, and carbonic acid which is a product of decomposition) are confined to one group—the hydro-carbons. And of this group, which is on the average characterized by comparative instability and inertness, these hydro-carbons found in living tissues, are among the most unstable and inert.

§ 3. Passing now to the substances which contain three of these chief organic elements, we have first to note that along with the greater atomic weight which mostly accompanies their increased complexity, there is, on the average, a further marked decrease of molecular mobility. Scarcely any of them maintain a gaseous state at ordinary temperatures. One class of them only, the alcohols and their derivatives, evaporate under the usual atmospheric pressure; but not rapidly unless heated. The fixed oils, though they show that molecular mobility implied by an habitually liquid state, show this in a lower degree than the alcoholic compounds; and they cannot be reduced to the gaseous state without decomposition. In their allies, the fats, which are solid unless heated, the loss of molecular mobility is still more marked. And throughout the whole series of the fatty acids, in which to a fixed proportion of oxygen there are successively added higher equimultiples of carbon and hydrogen, we see how the molecular mobility decreases with the increasing sizes of the atoms. In the amylaceous and saccharine group of compounds, solidity is the habitual state: such of them as can assume the liquid form, doing so only when heated to 300° or 400° F.; and decomposing when further heated, rather than become gaseous. Resins and gums exhibit general physical properties of like character and meaning.

In chemical stability these ternary compounds, considered as a group, are in a marked degree below the binary ones. The various sugars and kindred bodies, decompose at no very high temperatures. The oils and fats are also readily carbonized by heat. Resinous and gummy substances are easily made to render up some of their constituents. And the alcohols with their allies, have no great power of resisting decomposition. These bodies, formed by the union of oxygen, hydrogen and carbon, are also, as a class, chemically inactive. The formic and acetic are doubtless energetic acids; but the higher members of the fatty-acid series are easily separated from the bases with which they combine. Saccharic acid, too, is an acid of considerable power; and sundry of the vegetal acids possess a certain activity, though an activity far less than that of the mineral acids. But throughout the rest of the group, there is shown but a small tendency to combine with other bodies; and such com binations as are formed have usually little permanence.

The phenomena of isomerism and polymerism are of frequent occurrence in these ternary compounds. Starch and dextrine are isomeric. Fruit sugar, starch sugar, eucalyn, sorbin, and inosite, are polymeric. Sundry of the vegetal acids exhibit similar modifications. And among the resins and gums, with their derivatives, molecular re-arrangements of this kind are not uncommon.

One further fact respecting these compounds of carbon, oxygen and hydrogen, should be mentioned; namely, that they are divisible into two classes—the one consisting of substances that result from the destructive decomposition of organic matter, and the other consisting of substances that exist as such in organic matter. These two classes of substances exhibit in different degrees, the properties to which we have been directing our attention. The lower alcohols, their allies and derivatives, which possess greater molecular mobility and chemical stability than the rest of these ternary compounds, are not found in animal or vegetal bodies. While the sugars and amylaceous substances, the fixed oils and fats, the gums and resins, which have all of them much less molecular mobility, and are, chemically considered, more unstable and inert, are components of the living tissues of plants and animals.

§ 4. Among compounds containing all the four chief organic elements, a division analogous to that just named may be made. There are some which result from the decomposition of living tissues; there are others which make parts of living tissues in their state of integrity; and these two groups are contrasted in their properties in the same way as are the parallel groups of ternary compounds.

Of the first division, certain products found in the animal excretions are the most important, and the only ones that need be noted; such, namely, as urea, kreatine, kreatinine. These animal bases exhibit much less molecular mobility than the average of the substances treated of in the last section: being solid at ordinary temperatures, fusing, where fusible at all, at temperatures above that of boiling water, and having no power to assume a gaseous state. Chemically considered, their stability is low, and their activity but small, in comparison with the stabilities and activities of the simpler compounds.

It is, however, the nitrogenous constituents of living tissues, that display most markedly, those characteristics of which we have been tracing the growth. Albumen, fibrin, casein, and their allies, are bodies in which that molecular mobility exhibited by three of their components in so high a degree, is reduced to a minimum. These substances are known only in the solid state: that is to say, when deprived of the water usually mixed with them, they do not admit of fusion, much less of volatilization. To which add, that they have not even that molecular mobility which solution in water implies; since, though they form viscid mixtures with water, they do not dissolve in the same perfect way as do inorganic compounds. The chemical characteristics of these substances, are instability and inertness carried to the extreme. How rapidly albumenoid matters decompose under ordinary conditions, is daily seen: the difficulty of every house-wife being to prevent them from decomposing. It is true that when desiccated and kept from contact with air, they may be preserved unchanged for a long period; but the fact that they can only be thus preserved, proves their great instability. It is true, also, that these most complex nitrogenous principles are not absolutely inert; since they enter into combinations with some bases; but their unions are very feeble.

It should be noted, too, of these bodies, that though they exhibit in the lowest degree that kind of molecular mobility, which implies facile vibration of the atoms as wholes, they exhibit in a high degree that kind of molecular mobility resulting in isomerism, which implies permanent changes in the positions of adjacent atoms with respect to each other. Each of them has a soluble and insoluble form. In some cases there are indications of more than two such forms. And it appears that their metamorphoses take place under very slight changes of conditions.

In these most unstable and inert organic compounds, we find that the atomic complexity reaches a maximum: not only since the four chief organic elements are here united with small proportions of sulphur and phosphorus; but also since they are united in high multiples. The peculiarity which we found characterized even binary compounds of the organic elements, that their atoms are formed not of single equivalents of each component, but of two, three, four and more equivalents, is carried to the greatest extreme in these compounds, that take the leading part in organic actions. According to Mulder, the formula of albumen is 10 (C^{40} H^{31} N^5 O^{12}) + S^2 P. That is to say, with the sulphur and phosphorus there are united ten equivalents of a compound atom containing forty atoms of carbon, thirty-one of hydrogen, five of nitrogen, and twelve of oxygen: the atom being thus made up of nearly nine hundred ultimate atoms.

§ 5. Did space permit, it would be useful here to consider in detail, the interpretations that may be given of the peculiarities we have been tracing: bringing to their solution, those general mechanical principles which are now found to hold true of molecules as of masses. But it must suffice briefly to indicate the conclusions that such an inquiry promises to bring out.

Proceeding on mechanical principles, it may be argued that the molecular mobility of a substance must depend partly on the inertia of its molecules; partly on the intensity of their mutual polarities; partly on their mutual pressure, as determined by the density of their aggregation, and (where the molecules are compound) partly on the molecular mobilities of their component molecules. Whence it is to be inferred that any three of these remaining constant, the molecular mobility will vary as the fourth. Other things equal, therefore, the molecular mobility of atoms must decrease as their masses increase; and so there must result that general progression we have traced, from the high molecular mobility of the uncombined organic elements, to the low molecular mobility of those large-atomed substances into which they are ultimately compounded.

Applying to atoms the mechanical law which holds of masses, that since inertia and gravity increase as the cubes of the dimensions while cohesion increases as their squares, the self-sustaining power of a body becomes relatively smaller as its bulk becomes greater; it might be argued that these large, aggregate atoms which constitute organic substance, are mechanically weak—are less able than simpler atoms to bear, without alteration, the forces falling on them. That very massiveness which renders them less mobile, enables the physical forces acting on them more readily to change the relative positions of their component atoms; and so to produce what we know as re-arrangements and decompositions.

Further, it seems a not improbable conclusion, that this formation of large aggregates of elementary atoms, and resulting diminution of self-sustaining power, must be accompanied by a decrease of those contrasts of dimension to which polarity is ascribable. A sphere is the figure of equilibrium which any aggregate of units tends to assume, under the influence of simple mutual attraction. Where the number of units is small and their mutual polarities are decided, this proclivity towards spherical grouping will be overcome by the tendency towards some more special form, determined by their mutual polarities. But it is manifest that in proportion as an aggregate atom becomes larger, the effects of simple mutual attraction must become relatively greater; and so must tend to mask the effects of polar attraction. There will consequently be apt to result in highly compound atoms like these organic ones containing nine hundred elementary atoms, such approximation to the spherical form as must involve a less distinct polarity than in simpler atoms. If this inference be correct, it supplies us with an explanation both of the chemical inertness of these most complex organic substances, and of their inability to crystallize.

§ 6. Here we are naturally introduced to another aspect of our subject—an aspect of great interest. Professor Graham has recently published a series of important researches, which promise to throw much light on the constitution and changes of organic matter. He shows that solid substances exist under two forms of aggregation—the *colloid* or jelly-like, and the *crystalloid* or crystal-like. Examples of the last are too familiar to need specifying. Of the first may be named such instances as "hydrated silicic acid, hydrated alumina, and other metallic peroxides of the aluminous class, when they exist in the soluble form; with starch, dextrine and the gums, caramel, tannin, albumen, gelatine, vegetable and animal extractive matters." Describing the properties of colloids, Professor Graham says:—"Although often largely soluble in water, they are held in solution by a most feeble force. They appear singularly inert in the capacity of acids and bases, and in all the ordinary chemical relations." * * * "Although chemically inert in the ordinary sense, colloids possess a compensating activity of their own arising out of their physical properties. While the rigidity of the crystalline structure shuts out external impressions, the softness of the gelatinous colloid partakes of fluidity, and enables the colloid to become a medium of liquid diffusion, like water itself." * * * "Hence a wide sensibility on the part of colloids to external agents. Another and eminently characteristic quality of colloids is their mutability." * * * "The solution of hydrated silicic acid, for instance, is easily obtained in a state of purity, but it cannot be preserved. It may remain fluid for days or weeks in a sealed tube, but is sure to gelatinize and become insoluble at last. Nor does the change of this colloid appear to stop at that point; for the mineral forms of silicic acid, deposited from water, such as flint, are often found to have passed, during the geological ages of their existence, from the vitreous or colloidal into the crystalline condition (H. Rose). The colloid is, in fact, a dynamical state of matter, the crystalloidal being the statical condition. The colloid possesses *energia*. It may be looked upon as the primary source of the force appearing in the phenomena of vitality. To the gradual manner in which colloidal changes take place (for they always demand time as an element) may the characteristic protraction of chemico-organic changes also be referred."

The class of colloids includes not only all those most complex nitrogenous compounds characteristic of organic tissue,

acid, the true numbers of its formula must be several times greater. It is difficult to avoid associating the inertness of colloids with their high equivalents, particularly where the high number appears to be attained by the repetition of a small number. The inquiry suggests itself whether the colloid molecule may not be constituted by the grouping together of a number of smaller crystalloid molecules, and whether the basis of colloidality may not really be this composite character of the molecule."

§ 7. A further contrast between colloids and crystalloids, is equally significant in its relations to vital phenomena. Professor Graham points out that the marked differences in volatility displayed by different bodies, are paralleled by differences in the rates of diffusion of different bodies through liquids. As alcohol and ether at ordinary temperatures, and various other substances at higher temperatures, diffuse themselves in a gaseous form through the air; so, a substance in aqueous solution, when placed in contact with a mass of water (in such way as to avoid mixture by circulating currents) diffuses itself through this mass of water. And just as there are various degrees of rapidity in evaporation, so there are various degrees of rapidity in diffusion: "the range also in the degree of diffusive mobility exhibited by different substances appears to be as wide as the scale of vapour-tensions." This parallelism is what might have been looked for; since the tendency to assume a gaseous state, and the tendency to spread in solution through a liquid, are both consequences of molecular mobility. It also turns out, as was to be expected, that diffusibility, like volatility, has, other things equal, a relation to atomic weight—(other things equal, we must say, because molecular mobility must, as pointed out in § 5, be affected by other properties of atoms, besides their inertia). Thus the substance most rapidly diffused of any on which Professor Graham experimented, was hydro-chloric acid—a compound which is of low atomic weight, is gaseous save under a pressure of forty atmospheres, and ordinarily exists as a liquid, only in combination with water. Again, "hydrate of potash may be said to possess double the velocity of diffusion of sulphate of potash, and sulphate of potash again double the velocity of sugar, alcohol, and sulphate of magnesia,"—differences which have a general correspondence with differences in the massiveness of the atoms.

But the fact of chief interest to us here, is that the relatively small-atomed crystalloids have immensely greater diffusive power than the relatively large-atomed colloids. Among the crystalloids themselves, there are marked differences of diffusibility; and among the colloids themselves, there are parallel differences, though less marked ones. But these differences are small compared with that between the diffusibility of the crystalloids as a class, and the diffusibility of the colloids as a class. Hydro-chloric acid is seven times as diffusible as sulphate of magnesia; but it is fifty times as diffusible as albumen, and a hundred times as diffusible as caramel.

These differences of diffusibility manifest themselves with nearly equal distinctness, when a permeable septum is placed between the solution and the water. And the result is, that when a solution contains substances of different diffusibilities, the process of dialysis, as Professor Graham calls it, becomes a means of separating the mixed substances: especially when such mixed substances are partly crystalloids and partly colloids. The bearing of this fact on organic processes will be obvious. Still more obvious will its bearing be, on joining it with the remarkable fact, that while crystalloids can diffuse themselves through colloids nearly as rapidly as through water, colloids can scarcely diffuse themselves at all through other colloids. From a mass of jelly containing salt, into an adjoining mass of jelly containing no salt, the salt spread more in eight days than it spread through water in seven days; while the spread of "caramel through the jelly appeared scarcely to have begun after eight days had elapsed." So that we must regard the colloidal compounds of which organisms are built, as having by their physical nature, the ability to separate colloids from crystalloids, and to let the crystalloids pass through them with scarcely any resistance.

One other result of these researches on the relative diffusibilities of different substances, has a meaning for us. Professor Graham finds, that not only does there take place by dialysis, a separation of *mixed* substances which are unlike in their molecular mobilities; but also that *combined* substances between which the affinity is feeble, will separate on the dialyzer, if their molecular mobilities are strongly contrasted. Speaking of the hydro-chlorate of peroxide of iron, he says, "such a compound possesses an element of instability in the extremely unequal diffusibility of its constituents;" and he points out that when dialyzed, the hydro-chloric acid gradually diffuses away, leaving the colloidal peroxide of iron behind. Similarly, he remarks of the peracetate of iron, that it "may be made a source of soluble peroxide, as the salt referred to is itself decomposed to a great extent by diffusion on the dialyzer." Now this tendency to separate displayed by substances that differ widely in their molecular mobilities, though usually so far antagonized by their affinities as not to produce spontaneous decomposition, must, in all cases, induce a certain readiness to change which would not else exist. The unequal mobilities of the combined atoms, must give disturbing forces a greater power to work transformations than they would otherwise have. Hence the probable significance of a fact named at the outset, that while three of the chief organic elements have the greatest atomic mobilities of any elements known, the fourth, carbon, has the least atomic mobility of known elements. Though, in its simple compounds, the affinities of carbon for the rest are strong enough to prevent the effects of this great difference from clearly showing themselves; yet there seems reason to think, that in those complex compounds composing organic bodies—compounds in which there are various cross affinities leading to a state of chemical tension—this extreme difference in the molecular mobilities must be an important aid to molecular re-arrangements. In short, we are here led by concrete evidence to the conclusion which we before drew from first principles, that this great unlikeness among the combined units must facilitate differentiations.

§ 8. A portion of organic matter in a state to exhibit those phenomena which the biologist deals with, is, however, something far more complex than the separate organic matters we have been studying; since a portion of organic matter in its integrity, contains several of these.

In the first place, no one of those colloids which make up the mass of a living body, appears capable of carrying on vital changes by itself: it is always associated with other colloids. A portion of animal-tissue, however minute, almost always contains more than one form of protein-substance: different chemical modifications of albumen and gelatine are present together, as well as, probably, a soluble and insoluble modification of each; and there is usually more or less of fatty matter. In a single vegetal cell, the minute quantity of nitrogenous colloid present, is imbedded in colloids of the non-nitrogenous class. The microscope makes it at once manifest, that even the smallest and simplest organic forms are not absolutely homogeneous.

Further, we have to contemplate organic tissue, formed of mingled colloids in both soluble and insoluble states, as permeated throughout by crystalloids. Some of these crystalloids, as oxygen,* water, and perhaps certain salts, are agents of decomposition; some, as the saccharine and fatty

* It will perhaps seem strange to class oxygen as a crystalloid. But inasmuch as the crystalloids are distinguished from the colloids by their atomic simplicity, and inasmuch as sundry gases are reducible to a crystalline state, we are justified in so classing it.

matters, are probably materials for decomposition; and some, as carbonic acid, water, urea, kreatine, and kreatinine, are products of decomposition. Into the mass of mingled colloids, mostly insoluble and where soluble of very low molecular mobility or diffusive power, we have constantly passing, crystalloids of high molecular mobility or diffusive power, that are capable of decomposing these complex colloids; and from these complex colloids, so decomposed, there result other crystalloids (the two chief ones extremely simple and mobile, and the rest comparatively so) which diffuse away as rapidly as they are formed.

And now we may clearly see the necessity for that peculiar composition which we find in organic matter. On the one hand, were it not for the extreme molecular mobility possessed by three of its chief elements out of the four; and were it not for the consequently high molecular mobility of their simpler compounds; there could not be this quick escape of the waste products of organic action; and there could not be that continuously active change of matter which vitality implies. On the other hand, were it not for the union of these extremely mobile elements into immensely complex compounds, having relatively vast atoms that are made comparatively immobile by their inertia, there could not result that mechanical fixity which prevents the components of living tissue from diffusing away along with the effete matters produced by the decomposition of tissue.

§ 9. Thus in the substances of which organisms are composed, the conditions necessary to that re-distribution of Matter and Motion which constitutes Evolution, are fulfilled in a far higher degree than at first appears.

The mutual affinities of the chief organic elements are not active within the limits of those temperatures at which organic actions take place; and one of these elements is especially characterized by its chemical indifference. The compounds formed by these elements in ascending grades of complexity, become progressively less stable. And those most complex compounds into which all these four elements enter, together with small proportions of two other elements that very readily oxidize, have an instability so great that decomposition ensues under ordinary atmospheric conditions.

Among these elements out of which living bodies are built, there is an unusual tendency to unite in multiples; and so to form groups of products which have the same chemical components, but, being different in their modes of aggregation, possess different properties. This prevalence among them of isomerism and polymerism, shows, in another way, the special fitness of organic substances for undergoing re-distributions.

In those most complex compounds that are instrumental to vital actions, there exists a kind and degree of molecular mobility which constitutes the plastic quality fitting them for organization. Instead of the extreme molecular mobility possessed by three out of the four organic elements in their separate states—instead of the diminished, but still great, molecular mobility possessed by their simpler combinations, the gaseous and liquid characters of which unfit them for showing to any extent the process of Evolution—instead of the properties of their less simple combinations, which, when not made unduly mobile by heat, assume the unduly rigid form of crystals; we have in these colloids, of which organisms are mainly composed, just the required compromise between fluidity and solidity. They cannot be reduced to the unduly mobile conditions of liquid and gas; and yet they do not assume the unduly fixed condition usually characterizing solids. The absence of power to unite together in polar arrangement, leaves their atoms with a certain freedom of relative movement which makes them sensitive to small forces, and produces plasticity in the aggregates composed of them.

While the relatively great inertia of these large and complex organic atoms, renders them comparatively incapable of being set in motion by the ethereal undulations, and so reduced to less coherent forms of aggregation; there is reason to think that this same inertia facilitates changes of arrangement among their constituent atoms; since, in proportion as an incident force impresses but little motion on a mass, it is the better able to impress motion on the parts of the mass in relation to each other. And it is further probable that the extreme contrasts in molecular mobilities among the components of these highly complex atoms, aid in producing modifiability of arrangement among them.

Lastly, the great difference in diffusibility between colloids and crystalloids, makes possible in the tissues of organisms, a specially rapid re-distribution of matter and motion; both because colloids, being easily permeable by crystalloids, can be chemically acted on throughout their whole mass, instead of only on their surfaces; and because the products of decomposition, being also crystalloids, can escape as fast as they are produced, leaving room for further like transformations. So that while the composite atoms of which organic tissues are built up, possess that low molecular mobility fitting them for plastic purposes, it results from the extreme molecular mobilities of their ultimate constituents, that the waste products of vital activity escape as fast as they are formed.

To all which add, that the state of warmth, or increased molecular vibration, in which all the higher organisms are kept, increases these various facilities for re-distribution: not only as aiding chemical changes, but as accelerating the diffusion of crystalloid substances.

as well as other matter that assumes the same state of molecular aggregation.

Colloids take up by a power that has been called "capillary affinity," a large quantity of water: undergoing at the same time great increase of bulk with change of form. Conversely, with like readiness, they give up this water by evaporation: resuming more or less completely their original states. Whether resulting from capillarity, or from the relatively great diffusibility of water, or from both; these changes are to be here noted as showing another mode in which the arrangement of parts in organic bodies, is affected by mechanical forces.

In what is called osmose, we have a further mode of allied kind. When on opposite sides of a permeable septum, and especially a septum of colloidal substance, are placed miscible solutions of different densities, a double transfer takes place: a large quantity of the less dense solution finds its way through the septum into the more dense solution; and a small quantity of the more dense finds its way into the less dense—one result being a considerable increase in the bulk of the more dense at the expense of the less dense. This process, which appears to depend on several conditions, is not yet fully understood. But be the explanation what it may, the process is one that tends continually to work alterations in organic bodies. Through the surfaces of plants and animals, transfers of this kind are ever taking place. Very many of the conspicuous changes of form undergone by organic germs, are due mainly to the permeation of their limiting membranes by the surrounding liquids.

It should be added that besides the direct alterations which the imbibition and transmission of water and watery solutions by colloids produce in organic matter, they produce indirect alterations. Being instrumental in conveying into the tissues the agents of chemical change, and conveying out of them the products of chemical change, they aid in carrying on other re-distributions.

§ 12. As elsewhere shown (*First Principles*, § 103) Heat, or a raised state of molecular vibration, enables incident forces more easily to produce changes of molecular arrangement in organic matter. But besides this, it conduces to certain vital changes in so direct a way as to become their chief cause.

The power of the organic colloids to imbibe water, and to bring along with it into their substance the materials which work transformations, would not be continuously operative if the water imbibed were to remain. It is because it escapes, and is replaced by more containing more materials, that the succession of changes is maintained. Among the higher animals and higher plants its escape is facilitated by evaporation. And the rate of evaporation is, other things equal, determined by heat. Though the current of sap in a tree is mainly caused by some action, probably osmotic, that is at work in the roots; yet the loss of water from the surfaces of the leaves, and the consequent absorption of more sap into the leaves by capillary attraction, must largely aid the circulation. The drooping of a plant when exposed to the sunshine while the earth round its roots is dry, shows us how evaporation empties the sap-vessels; and the quickness with which a withered slip revives on being placed in water, shows us the part which capillary action plays In so far then, as the evaporation from a plant's surface helps to produce currents of sap through the plant, we must regard the heat which produces this evaporation as a part-cause of those re-distributions of matter which these currents effect. In terrestrial animals, heat similarly aids the changes that are going on. The exhalation of vapour from the lungs and the surface of the skin, forming the chief escape of the water that is swallowed, conduces to the maintenance of those currents through the tissues, without which the functions would cease. For though the vascular system distributes nutritive fluids in ramified channels through the body; yet the absorption of these fluids into tissues, partly depends on the escape of fluids which the tissues already contain. Hence, to the extent that such escape is facilitated by evaporation, and this evaporation facilitated by heat, heat becomes an agent of re-distribution in the animal organism.

§ 13. Light, which is now known to modify many inorganic compounds—which works those chemical changes utilized in photography, causes the combinations of certain gases, alters the molecular arrangements of many crystals, and leaves traces of its action even on substances that are extremely stable,—may be expected to produce marked effects on substances so complex and unstable as those which make up organic bodies. It does produce such marked effects; and some of them are among the most important that organic matter undergoes.

The molecular changes wrought by light in animals, are but of secondary moment. There is the darkening of the skin that follows exposure to the sun's rays. There are those alterations in the retina which cause in us sensations of colours. And on certain eyeless creatures that are semi-transparent, the light permeating their substance works some effect evinced by movement. But speaking generally, the opacity of animals limits the action of light to their surfaces; and so renders its direct physiological influence but small.* On plants, however, the solar rays that produce in us the impression of yellow, are the immediate agents of those molecular changes through which are hourly accumulated the materials for further growth. Experiments have shown that when the sun shines on living leaves, they begin to exhale oxygen and to accumulate carbon and hydrogen—results which are traced to the decomposition by the solar rays, of the carbonic acid and water absorbed. It is now an accepted conclusion that, by the help of certain

* The increase of respiration found to result from the presence of light, is probably an *indirect effect*. It is most likely due to the reception of more vivid impressions through the eyes, and to the consequent nervous stimulation.

classes of the ethereal undulations penetrating their leaves, plants are enabled to separate from the associated oxygen, those two elements of which their tissues are chiefly built up.

This transformation of ethereal undulations into certain molecular re-arrangements of an unstable kind, on the overthrow of which the stored-up forces are liberated in new forms, is a process that underlies all organic phenomena. It will therefore be well, if we pause a moment to consider whether any proximate interpretation of it is possible. Certain recent researches in molecular physics, give us some clue to its nature.

The elements of the problem are these:—The atoms of several ponderable matters exist in combination: those that are combined having strong affinities, but having also affinities less strong for some of the surrounding atoms that are otherwise combined. The atoms thus united, and thus mixed among others with which they are capable of uniting, are exposed to the undulations of a medium that is relatively so rare as to seem imponderable. These undulations are of numerous kinds: they differ greatly in their lengths, or in the frequency with which they recur at any given point. And under the influence of undulations of a certain frequency, some of these atoms are transferred from atoms for which they have a stronger affinity, to atoms for which they have a weaker affinity. That is to say, particular orders of waves of a relatively imponderable matter, remove particular atoms of ponderable matter from their attachments, and carry them within reach of other attachments. Now the discoveries of Bunsen and Kirchoff respecting the absorption of particular luminiferous undulations by the vapours of particular substances, joined with Prof. Tyndall's discoveries respecting the absorption of heat by gases, show very clearly that the atoms of each substance have a rate of vibration in harmony with ethereal waves of a certain length, or rapidity of recurrence. Every special kind of atom can be made to oscillate by a special order of ethereal waves, which are absorbed in producing its oscillations; and can by its oscillations generate this same order of ethereal waves. Whence it appears that immense as is the difference in density between ether and ponderable matter, the waves of the one can set the atoms of the other in motion, when the successive impacts of the waves are so timed as to correspond with the oscillations of the atoms. The effects of the waves are, in such case, cumulative; and each atom gradually acquires a momentum made up of countless infinitesimal momenta. Note further, that unless the members of a chemically-compound atom are so bound up as to be incapable of any relative movements (a supposition at variance with the conceptions of modern science) we must conceive them as severally able to vibrate in unison or harmony with those same classes of ethereal waves that affect them in their uncombined states. While the compound atom as a whole, will have some new rate of oscillation determined by its attributes as a whole; its components will retain their original rates of oscillation, subject only to modifications by mutual influence. Such being the circumstances of the case, we may partially understand how the sun's rays can effect chemical decompositions. If the members of a binary atom stand so related to the undulations falling on them, that one is thrown into a state of increased oscillation and the other not; it is manifest that there must arise a tendency towards the dislocation of the two—a tendency which may or may not take effect, according to the weakness or strength of their union, and according to the presence or absence of collateral affinities. This inference is in harmony with several significant facts. Dr Draper remarks that "among metallic substances (compounds) those first detected to be changed by light, such as silver, gold, mercury, lead, have all high atomic weights; and such as sodium and potassium, the atomic weights of which are low, appeared to be less changeable." As here interpreted, the fact specified amounts to this; that the compounds most readily decomposed by light, are those in which there is a marked contrast between the atomic weights of the constituents, and probably therefore a marked contrast between the rapidities of their vibrations. The circumstance, too, that different chemical compounds are decomposed or modified in different parts of the spectrum, implies that there is a relation between special orders of undulations and special orders of composite atoms—doubtless a correspondence between the rates of these undulations and the rates of oscillation which some of the components of such atoms will assume. Strong confirmation of this view may be drawn from the decomposing actions of those longer ethereal waves which we perceive as heat. On contemplating the whole series of binary compounds, we see that the elements which are most remote in their atomic weights, as hydrogen and the noble metals, will not combine at all: their vibrations are so unlike that they cannot keep together under any conditions of temperature. If again we look at a smaller group, as the metallic oxides, we see that whereas those metals that have atoms nearest in weight to the atoms of oxygen, cannot be separated from oxygen by heat, even when it is joined by a powerful collateral affinity; those metals which differ more widely from oxygen in their atomic weights, can be de-oxidized by carbon at high temperatures; and those which differ from it most widely, combine with it very reluctantly, and yield it up if exposed to thermal undulations of moderate intensity. And here indeed, remembering the relations among the atomic weights in the two cases, may we not suspect a close analogy between the de-oxidation of a metallic oxide by carbon under the influence of the longer ethereal waves, and the de-carbonization of carbonic acid by hydrogen under the influence of the shorter ethereal waves?

These conceptions help us to some dim notion of the mode in which changes are wrought by light in the leaves of plants. Among the several elements concerned, there are wide differences in molecular mobility, and probably in the rates of molecular vibration. Each is combined with one of the others; but is capable of forming various combinations with the rest. And they are severally in presence of a complex compound into which they all enter, and which is ready to assimilate with itself the new compound atoms that they form. Certain of the ethereal waves falling on them when thus arranged, there results a detachment of some of the combined atoms and a union of the rest. And the conclusion suggested is, that the induced vibrations among the various atoms as at first arranged, are so incongruous as to produce instability; and to give collateral affinities the power to work a re-arrangement, which, though less stable under other conditions, is more stable in the presence of these particular undulations. There seems, indeed, no choice but to conceive the matter thus. An atom united with one for which it has a strong affinity, has to be transferred to another for which it has a weaker affinity. This transfer implies motion. The motion is given by the waves of a medium that is relatively imponderable. No one wave of this imponderable medium can give the requisite motion to this atom of ponderable matter: especially as the atom is held by a positive force besides its inertia. The motion required can hence be given only by successive waves; and that these may not destroy each other's effects, it is needful that each shall strike the atom just when it has completed that recoil produced by the impact of previous ones. That is, the ethereal undulations must coincide in rate with the oscillations of the atom, determined by its inertia and the forces acting on it. It is also requisite that the rate of oscillation of the atom to be detached, shall differ from that of the atom with which it is united; since if the two oscillated in unison, the ethereal waves would not tend to separate them. And, finally, the successive impacts of the ethereal waves must be accumulated, until the resulting oscillations have become so wide in their sweep as greatly to weaken the cohesion of the united atoms, at the same time

those milder effects termed medicinal—effects implying, like the others, molecular re-arrangements. Indeed, nearly all soluble chemical compounds, natural and artificial, produce, when taken into the body, alterations that are more or less conspicuous in their results.

After what was shown in the last chapter, it will be manifest that this extreme modifiability of organic matter by chemical agencies, is the chief cause of that active molecular re-arrangement which organisms, and especially animal organisms, display. In the two fundamental functions of nutrition and respiration, we have the means by which the supply of materials for this active molecular re-arrangement is maintained.

Thus the process of animal nutrition consists in the absorption, partly of those complex substances that are thus highly capable of being chemically altered, and partly in the absorp tion of simpler substances capable of chemically altering them. The tissues always contain small quantities of alkaline and earthy salts, which enter the system in one form and are excreted in another. Though we do not know specifically the parts which these salts play, yet from their universal presence, and from the transformations which they undergo in the body, it may be safely inferred that their chemical affinities are instrumental in working some of the metamorphoses ever going on.

The inorganic substance, however, on which mainly depend these metamorphoses in organic matter, is not swallowed along with the solid and liquid food, but is absorbed from the surrounding medium—air or water, as the case may be. Whether the oxygen taken in, either, as by the lowest animals, through the general surface, or, as by the higher animals, through respiratory organs, is the immediate cause of those molecular changes that are ever going on throughout the living tissues; or whether the oxygen, playing the part of scavenger, merely aids these changes by carrying away the products of decompositions otherwise caused; it equally remains true, that these changes are maintained by its instrumentality. Whether the oxygen absorbed and diffused through the system, effects a direct oxidation of the organic colloids which it permeates; or whether it first leads to the formation of simpler and more oxidized compounds, that are afterwards further oxidized and reduced to still simpler forms; matters not, in so far as the general result is concerned. In any case it holds good, that the substances of which the animal body is built up, enter it in a but slightly oxidized and highly unstable state; while the great mass of them leave it in a fully oxidized and stable state. It follows, therefore, that whatever the special changes gone through, the general process is a falling from a state of unstable chemical equilibrium, to a state of stable chemical equilibrium. Whether this process be direct or indirect, the total molecular re-arrangement and the total motion given out in effecting it, must be the same.

§ 15. There is another species of re-distribution among the component units of organisms, which is not immediately effected by the affinities of the units concerned, but is mediately effected by other affinities; and there is reason to think that the re-distribution thus caused, is important in amount, if not indeed the most important. In ordinary cases of chemical action, the two or more substances concerned, themselves undergo changes of molecular arrangement; and the changes are confined to the substances themselves. But there are other cases in which the chemical action going on, does not end with the substances at first concerned; but sets going chemical actions, or changes of molecular arrangement, among surrounding substances that would else remain quiescent. And there are yet further cases in which mere contact with a substance that is itself quiescent, will cause other substances to undergo rapid metamorphoses. In what we call fermentation, the first species of this communicated chemical action is exemplified. One part of yeast, while itself undergoing molecular changes, will convert 100 parts of sugar into alcohol and carbonic acid; and during its own decomposition, one part of diastase "is able to effect the transformation of more than 1000 times its weight of starch into sugar." As illustrations of the second species, may be mentioned those changes which are suddenly produced in many colloids by minute portions of various substances added to them—substances that are not undergoing any manifest transformation, and suffer no appreciable effect from the contact. The nature of the first of these two kinds of communicated molecular change, which here chiefly concerns us, may be rudely represented by certain visible changes that are communicated from mass to mass, when a series of masses has been arranged in a special way. The simplest example is that furnished by the child's play of setting bricks on end in a row, in such positions that when the first is overthrown it overthrows the second; the second, the third; the third, the fourth; and so on to the end of the row. Here we have a number of units severally placed in unstable equilibrium, and in such relative positions that each, while falling into a state of stable equilibrium, gives an impulse to the next, sufficient to make the next, also, fall from unstable to stable equilibrium. Now since among mingled compound atoms, no one can undergo change in the arrangement of its parts without a molecular motion that must cause some disturbance all around; and since an adjacent atom disturbed by this communicated motion, may have the arrangement of its constituent molecules altered, if it is not a stable arrangement; and since we know, both that the atoms which are changed by this so-called catalysis *are* unstable, and that the atoms resulting from their change are *more* stable; it seems probable that the transformation is really analogous, in principle, to the familiar one named. Whether thus interpretable or not, however, there is great reason for thinking that to this kind of action, is due a large amount of vital metamorphosis. Let us contemplate the several groups of facts which point to this conclusion.

In the last chapter (§ 2) we incidentally noted the extreme instability of nitrogenous compounds in general. We saw that sundry of them are liable to explode on the slightest incentive—sometimes without any apparent cause; and that of the rest, the great majority are very easily decomposed by heat, and by other substances. We shall perceive much significance in this general characteristic, when we join it with the fact, that the substances capable of initiating extensive molecular changes in the manner above described, are all nitrogenous ones. Yeast consists of vegetal cells containing nitrogen,—cells that grow by assimilating the nitrogenous matter contained in wort. Similarly, the "vinegar-plant," which so greatly facilitates the formation of acetic acid from alcohol, is a fungoid growth, that is doubtless, like others of its class, rich in nitrogenous compounds. Diastase, by which the transformation of starch into sugar is effected, during the process of malting, is also a nitrogenous body. So too is a substance called synaptase—an albumenous principle contained in almonds, that has the power of working several metamorphoses in the matters associated with it. These nitrogenized compounds, like the rest of their family, are remarkable for the rapidity with which they decompose; and the extensive changes produced by them in the accompanying oxy-hydro-carbons, are found to vary in their kinds according as the decompositions of the ferments vary in their stages. We have next to note, as having here a meaning for us, the chemical contrasts between those organisms which carry on their functions by the help of external forces, and those which carry on their functions by forces evolved from within. If we compare animals and plants, we see that whereas plants, characterized as a class by containing but little nitrogen, are dependent on the solar rays for their vital activities; animals, the vital activities of which are not thus dependent, mainly consist of nitrogenous substances. There is one marked exception to this broad distinction, however; and this exception is specially instructive. Among plants, there is a considerable group—the Fungi—many members of which, if not all, can live and grow in the dark; and it is their peculiarity that they are very much more nitrogenous than other plants. Yet a third class of facts of like significance, is disclosed when we compare different portions of the same organisms. The seed of a plant contains nitrogenous substance in a far higher ratio than the rest of the plant; and the seed differs from the rest of the plant in its ability to initiate, in the absence of light, extensive vital changes—the changes constituting germination. Similarly in the bodies of animals, those parts which carry on active functions are nitrogenous; while parts that are non-nitrogenous—as the deposits of fat—carry on no active functions. And we even find that the appearance of non-nitrogenous matter, throughout tissues normally composed almost wholly of nitrogenous matter, is accompanied by loss of activity: what is called fatty degeneration, being the concomitant of failing vitality. One more fact which serves to make still clearer the meaning of the foregoing ones, still remains—the fact, namely, that in no part of any organism where vital changes are going on, is nitrogenous matter wholly absent. It is common to speak of plants—or at least all parts of plants but the seeds—as non-nitrogenous. But they are only relatively so; not absolutely. The quantity of albumenoid substance contained in the tissues of plants, is extremely small compared with the quantity contained in the tissues of animals; but all plant-tissues which are discharging active functions, contain some albumenoid substance. In every living vegetal cell there is a certain part that contains nitrogen. This part initiates those changes which constitute the development of the cell. And if it cannot be said that the *primordial utricle*, as this nitrogenous part is called, is the worker of all subsequent changes undergone by the cell, it nevertheless continues to be the part in which the independent activity is most marked.

Looking at the evidence thus brought together, do we not get an insight into the part played by nitrogenous matter in organic changes? We see that nitrogenous compounds in general, are extremely prone to decompose: their decomposition often involving a sudden and great evolution of force. We see that the substances classed as ferments, which, during their own molecular changes, set up molecular changes in the accompanying oxy-hydro-carbons, are all nitrogenous. We see that among classes of organisms, and among the parts of each organism, there is a relation between the amount of nitrogenous matter present and the amount of independent activity. And we see that even in organisms and parts of organisms where the activity is least, such changes as do take place are initiated by a substance containing nitrogen. Does it not seem probable, then, that these extremely unstable compounds, have everywhere the effect of communicating to the less unstable compounds associated with them, molecular movements towards a stable state, like those they are themselves undergoing? The changes which we thus suppose nitrogenous matter to produce in a body, are clearly analogous to those which we see it produce out of the body. Out of the body, certain oxy-hydro-carbons in continued contact with nitrogenous matter, are transformed into carbonic acid and alcohol, and unless prevented the alcohol is transformed into acetic acid: the substances formed being thus more highly oxidized and more stable than the substances destroyed. In the body, these same oxy-hydro-carbons together with some hydro-carbons, in continued contact with nitrogenous matter, are transformed into carbonic acid and water: substances which are also more highly oxidized and more stable than those from which they result. And since acetic acid is itself resolved by further oxidation into carbonic acid and water; we see that the chief difference between the two cases, is, that the process is more completely effected in the body, than it is out of the body.* Thus, to carry further the simile used above, the atoms of hydro-carbons and oxy-hydro-carbons contained in the tissues, are, like bricks on end, not in the stablest equilibrium, but still in an equilibrium so stable, that they cannot be overthrown by the chemical and thermal forces which the body brings to bear on them. On the other hand, being like similarly-placed bricks that have very narrow ends, the nitrogenous atoms contained in the tissues are in so unstable an equilibrium that they cannot withstand these forces. And when those delicately-poised nitrogenous atoms fall into stable arrangements, they give impulses to the more firmly-poised non-nitrogenous atoms, which cause them also to fall into stable arrangements. It is a curious and significant fact, that in the arts, we not only utilize this same principle of initiating extensive changes among comparatively stable compounds, by the help of compounds much less stable; but we employ for the purpose compounds of the same general class. Our modern method of firing a gun, is to place in close proximity with the gunpowder which we wish to decompose or explode, a small portion of fulminating powder, which is decomposed or exploded with extreme facility; and which, on decomposing, communicates the consequent molecular disturbance to the less-easily decomposed gunpowder. When we ask what this fulminating powder is composed of, we find that it is a nitrogenous salt.

Thus various evidences point to the conclusion, that besides the molecular re-arrangements produced in organic matter by direct chemical action, there are others of kindred importance produced by indirect chemical action. Indeed, the inference

* May it not be well to inquire whether alcohol is not, in a greater or less measure, transformed in the body into acetic acid? If, when in contact with changing nitrogenous matter, in presence of oxygen, alcohol undergoes this transformation out of the body, it seems not improbable that it does so in the body—especially as the raised temperature which aids the change in the one case exists in the other. It would be out of place here to set down the sundry facts which countenance this hypothesis. I may say, however, that it apparently removes some of the difficulties which at present perplex the question.

CHAPTER III.

THE RE-ACTIONS OF ORGANIC MATTER ON FORCES.

§ 17. RE-DISTRIBUTIONS of Matter, imply concomitant re-distributions of Motion. That which under one of its aspects we contemplate as an alteration of arrangement among the parts of a body, is, under a correlative aspect, an alteration of arrangement among certain momenta whereby these parts are impelled to their new positions. At the same time that a force, acting differently on the different units of an aggregate, changes their relations to each other; these units, re-acting differently on the different parts of the force, work equivalent changes in the relations of these to one another. Inseparably connected as they are, these two orders of phenomena are liable to be confounded together. It is very needful, however, to distinguish between them. In the last chapter, we took a rapid survey of the re-distributions which forces produce in organic matter; and here we must take a like survey of the simultaneous re-distributions undergone by the forces.

At the outset we are met by a difficulty. The parts of an inorganic mass undergoing re-arrangement by an incident force, are, in most cases, passive—do not complicate those necessary re-actions that result from their inertia, by other forces which they originate. But in organic matter, the re-arranged parts do not re-act in virtue of their inertia only: they are so constituted that the incident force usually sets up in them, other actions which are much more important. Indeed, what we may call the indirect re-actions thus caused, are so great in their amounts compared with the direct re-actions, that they quite obscure them.

In strictness, these two kinds of re-action should not be dealt with together. The impossibility of separating them, however, compels us to disregard the distinction between them. Under the above general title, we must include both the immediate re-actions and those re-actions mediately produced, which are among the most conspicuous of vital phenomena.

§ 18. From organic matter, as from all other matter, incident forces call forth that re-action which we know as heat. More or less of molecular vibration almost necessarily results, when, to the forces at work among the molecules of any aggregate, other forces are added. Experiment abundantly demonstrates this in the case of inorganic masses; and it must equally hold in the case of organic masses. In both cases the force which, more markedly than any other, produces this thermal re-action, is that which causes the union of different substances with each other. Though inanimate bodies admit of being greatly heated by pressure and by the electric current, yet the evolutions of heat thus induced, are neither so common, nor in most cases so conspicuous, as those resulting from chemical combination. And though in animate bodies, there are doubtless certain amounts of heat generated by other actions; yet these are all secondary to the heat generated by the action of oxygen on the substances composing the tissues and the substances contained in them. Here, however, we see one of the characteristic distinctions between inanimate and animate bodies. Among the first, there are but few which ordinarily exist in a condition to evolve the heat caused by chemical combination; and such as are in this condition soon cease to be so, when chemical combination and genesis of heat once begin in them. Whereas among the second, there universally exists the ability, more or less decided, thus to evolve heat; and the evolution of heat, in some cases very slight and in no cases very great, continues as long as they remain animate bodies.

The relation between active change of matter and re-active genesis of atomic vibration, is clearly shown by the contrasts between different organisms, and between different states and parts of the same organism. In plants, the genesis of heat is extremely small, in correspondence with their extremely small production of carbonic acid: those portions only, as flowers and germinating seeds, in which considerable oxidation is going on, having a decidedly raised temperature. Among animals, we see that the hot-blooded are those which expend much force and respire actively. We see that though such creatures as insects are scarcely at all warmer than the surrounding air when they are still, they rise several degrees above it when they exert themselves; and that in creatures like ourselves, which habitually maintain a heat much greater than that of their medium, exercise is accompanied by an additional production of heat, often to an inconvenient extent.

This molecular agitation accompanying the molecular re-arrangements that are caused by oxygen taken into the animal organism, must result both from the union of oxygen with those nitrogenous matters of which the tissues are composed, and from its union with those non-nitrogenous matters which are diffused through the tissues. Just as much heat as would be caused by the oxidation of such matters out of the body, must be caused by their oxidation in the body. In the one case as in the other, the heat must be regarded as a concomitant. Whether the distinction made by Liebig between nitrogenous substances as tissue-food, and non-nitrogenous substances as heat-food, be true or not in a narrower sense, it cannot be accepted in the sense that tissue-food is not also heat-food. Indeed he does not himself assert it in this sense. The ability of carnivorous animals to live and generate heat while consuming matter that is almost exclusively nitrogenous, to say nothing of the constant relation above shown between functional activity and the evolution of heat, suffices to prove that the nitrogenous compounds forming the tissues are heat-producers, as well as the non-nitrogenous compounds circulating among and through the tissues. But it is possible that this antithesis is not true even in the more restricted sense. It seems quite an admissible hypothesis that the hydro-carbons and oxy-hydrocarbons which, in traversing the system, are transformed by communicated chemical action, evolve during their transformation, not heat alone, but also other kinds of force. It may be that as the nitrogenous matter, while falling into more stable molecular arrangements, generates both that molecular agitation called heat, and such other molecular movements as are resolved into forces expended by the organism; so, too, does the non-nitrogenous matter. Or perhaps the concomitants of this metamorphosis of non-nitrogenous matter, vary with the conditions. Heat alone may result when it is transformed while in the circulating fluids, but partly heat, and partly another force, when it is transformed in some active tissue that has absorbed it: just as coal, though producing little else but heat as ordinarily burnt, has its heat partially transformed into mechanical motion if burnt in a steam-engine furnace. In such case, the antithesis of Liebig would be reduced to this; —that whereas nitrogenous substance is tissue-food *both* as material for building-up tissue and as material for its function; non-nitrogenous substance is tissue-food *only* as material for function.

There can be no doubt that this thermal re-action which chemical action from moment to moment produces in the body, is from moment to moment an aid to further chemical action. We before saw (*First Principles*, § 103) that a state of raised molecular vibration, is favourable to those re-distributions of matter and motion which constitute Evolution. We saw that in organisms distinguished by the amount and rapidity of such re-distributions, this raised state of molecular vibration is conspicuous. And we here see that this raised state of molecular vibration, is itself a continuous consequence of the continuous molecular re-distributions it facilitates. The heat generated by each increment of chemical change, makes possible the succeeding increment of chemical change. In the body this connexion of phenomena is the same as we see it to be out of the body. Just as in a burning piece of wood, the heat given out by the portion actually combining with oxygen, raises the adjacent portion to a temperature at which it also can combine with oxygen; so, in a living animal, the heat produced by oxidation of each portion of tissue, maintains the temperature at which the unoxidized portions can be readily oxidized.

§ 19. Among the forces called forth from organisms by re-action against the actions to which they are subject, is Light. Phosphorescence is in some few cases displayed by plants—especially by certain fungi. Among animals it is comparatively common. All know that there are several kinds of luminous insects; and many are familiar with the fact that luminosity is a characteristic of various marine creatures.

Most of the evidence goes to show that this evolution of light, as well as the evolution of heat, is consequent on oxidation of the tissues. Light, like heat, is the expression of a raised state of molecular vibration: the difference between them being a difference in the rates of vibration. Hence by chemical action on substances contained in the organism, heat or light may be produced, according to the character of the resulting molecular vibrations. The inference that oxidation is the cause of this luminosity, does not, however, rest only on *à priori* grounds. It is supported by experimental evidence. In phosphorescent insects, the continuance of the light is found to depend on the continuance of respiration; and any exertion which renders respiration more active, increases the brilliancy of the light. Moreover, by separating the luminous matter, Prof. Matteucci has shown that its emission of light is accompanied by absorption of oxygen and escape of carbonic acid. The phosphorescence of marine animals has been referred to other causes than oxidation. In some cases, however, it is, I think, explicable without assuming any more special agency. Considering that in creatures of the genus *Noctiluca*, for example, to which the phosphorescence most commonly seen on our own coasts is due, there is no means of keeping up a constant circulation, we may infer that the movements of aerated fluids through their tissues, must be greatly affected by impulses received from without. Hence it may be that the sparkles visible at night when the waves break gently on the beach, or when an oar is dipped into the water, are called forth from these creatures by the concussion, not because of any unknown influence it excites, but because, being propagated through their delicate tissues, it produces a sudden movement of the fluids and a sudden increase of chemical action. Nevertheless, in other phosphorescent animals inhabiting the sea, as in the *Pyrosoma* and in certain *Annelida*, light seems to be really produced, not by direct re-action on the action of oxygen, but by some indirect re-action involving a transformation of force.

§ 20. The re-distributions of matter in general, are accompanied by electrical disturbances; and there is abundant evidence that electricity is generated during those re-distributions that are ever taking place in organisms. Experiments have shown "that the skin and most of the internal membranes are in opposite electrical states;" and also that between different internal organs, as the liver and the stomach, there are electrical contrasts—such contrasts being greatest where the processes going on in the compared parts are most unlike. It has been proved by M. du Bois-Reymond that when any point in the longitudinal section of a muscle is connected by a conductor with any point in its transverse section, an electric current is established; and further, that like results occur when nerves are substituted for muscles. The special causes of these phenomena have not yet been determined. Considering that the electric contrasts are most marked where active secretions are going on—considering, too, that while they do not exist between external parts which are similarly related to the vascular currents, they do exist between external parts which are dissimilarly related to the vascular currents—and considering also that they are extremely difficult to detect where there are no appreciable movements of fluids; it may be that they are due simply to the friction of heterogeneous substances, which is universally a cause of electric disturbance. But whatever be the interpretation, the fact remains the same, that there is throughout the living organism, an unceasing production of differences between the electric states of different parts; and consequently an unceasing restoration of electric equilibrium by the establishment of currents among these parts.

Besides these general, and not conspicuous, electrical phenomena which appear to be common to all organisms, vegetal as well as animal, there are certain special and strongly marked ones. I refer, of course, to those which have made the *Torpedo* and the *Gymnotus* objects of so much interest. In these creatures we have a genesis of electricity that is not incidental on the performance of their different functions by the different organs; but one which is itself a function, having an organ appropriate to it. The character of this organ in both these fishes, and its largely-developed connexions with the nervous centres, have raised the suspicion, which various experiments have thus far justified, that in it there takes place a transformation of what we call nerve-force into the force known as electricity: this conclusion being more especially supported by the fact, that substances, such as morphia and strychnia, which are known to be powerful

beget actions in muscles or other organs. Besides neural discharges that follow the direct incidence of external forces, there are others ever being caused by the incidence of forces which, though originally external, have become internal by absorption into the organism of the agents exerting them. For thus may be classed those neural discharges that from moment to moment result from modifications of the tissues, wrought by substances carried to them in the blood. That the unceasing change of matter which oxygen and other agents produce throughout the system, is accompanied by a genesis of nerve-force, is shown by various facts;—by the fact that nerve-force is no longer generated, if oxygen be withheld, or the blood prevented from circulating; by the fact that when the chemical transformation is diminished, as during sleep with its slow respiration and circulation, there is a diminution in the quantity of nerve-force; in the fact that an excessive expenditure of nerve-force, involves excessive respiration and circulation, and excessive waste of tissue. To these proofs that nerve-force is evolved in greater or less quantity, according as the conditions to rapid molecular change throughout the body, are well or ill fulfilled; may be added proofs that certain special molecular actions, are the causes of these special re-actions. The effects of alcohol, ether, chloroform, and the vegeto-alkalies, put beyond doubt the inference, that the overthrow of molecular equilibrium by chemical affinity, when it occurs at certain places in the body, results in the overthrow of equilibrium in the nerves proceeding from these places—results, that is, in the propagation through these nerves, of the change called a nervous discharge. Indeed, looked at from this point of view, the two classes of nervous changes—the one initiated from without and the other from within—are seen to merge into one class. Both of them may be traced to metamorphosis of tissue. There can be little doubt that the sensations of touch and pressure, are consequent on accelerated changes of matter, produced by mechanical disturbance of the mingled fluids and solids composing the parts affected. There is abundant evidence that the sensation of taste, is due to the chemical actions set up by particles which find their way through the membrane covering the nerves of taste; for, as Prof. Graham points out, sapid substances all belong to the class of crystalloids, which are able rapidly to permeate animal tissue, while colloids, which cannot pass through animal tissue, are all insipid. Similarly with the sense of smell. Substances which excite this sense, are necessarily more or less volatile; and their volatility being the result of their molecular mobility, implies that they have in a high degree, the power of getting at the olfactory nerves by penetrating their mucous investment. Again, the facts which photography has familiarized us with, make it clear that those nervous impressions called colours, are primarily due to certain changes wrought by light in the substance of the retina. And though, in the case of hearing, we cannot so clearly trace the connexion of cause and effect; yet as we see that the auditory apparatus is one fitted to intensify those vibrations constituting sound, and to convey them to a receptacle containing fluid in which nerves are immersed; it can scarcely be doubted that the sensation of sound proximately results from atomic re-arrangements caused in these nerves by the vibrations of the fluid: knowing, as we do, that the re-arrangement of atoms is in all cases aided by agitation. Perhaps, however, the best proof that nerve-force, whether peripheral or central in its origin, results from chemical transformation, lies in the fact that most of the chemical agents which powerfully affect the nervous system, affect it whether applied at the centre or the periphery. Various acids, mineral and vegetal, are tonics—the stronger ones being usually the stronger tonics; and this which we call their acidity, implies a power in them of acting on the nerves of taste, while the tingling or pain that follows their absorption through the skin, implies that the nerves of touch are acted on by them. Similarly with certain vegeto-alkalies which are peculiarly bitter. These by their bitterness, show that they affect the extremities of the nerves; while by their tonic properties, they show that they affect the nervous centres—the most intensely bitter among them, strychnia, being the most powerful nervous stimulant. However true it may be that this relation is not a regular one, since opium, hashish, and some other drugs, which work marked effects on the brain, are not remarkably sapid—however true it may be that there are relations between particular substances and particular parts of the nervous system; yet such instances do but qualify, without negativing, the general proposition. The truth of this proposition can scarcely be doubted when, to the evidence above given, is added the fact that various condiments and aromatic drugs are given as nervous stimulants; and the fact that anæsthetics, besides the general effects they produce when inhaled or swallowed, produce local effects of like kind when absorbed through the skin; and the fact that ammonia, which in consequence of its extreme molecular mobility, so quickly and so violently excites the nerves beneath the skin, as well as those of the tongue and the nose, is a rapidly-acting stimulant when taken internally.

Whether we shall ever know anything more of this nerve-force, than that it is some species of molecular disturbance that is propagated from end to end of a nerve, it is impossible to say. Whether a nerve is merely a conductor, which delivers at one of its extremities an impulse received at the other; or whether, as some now think, it is itself a generator of force which is initiated at one extremity and accumulates in its course to the other extremity; are also questions which cannot yet be answered. All we know is, that forces capable of working molecular changes in nerves, are capable of calling forth from them manifestations of activity—discharges of some force, which, though probably allied to electricity, is not identical with it. And our evidence that nerve-force is thus originated, consists not only of such facts as the above, but also of more conclusive facts established by direct experiments on nerves—experiments which show that nerve-force is generated when the cut end of a nerve is either mechanically irritated, or acted on by some chemical agent, or subject to the galvanic current—experiments which thus prove that nerve-force is liberated by whatever disturbs the molecular equilibrium of nerve-substance. And this is all which it is necessary for us here to understand.

§ 22. The most important of these re-actions called forth from organisms by surrounding actions, remains to be noticed. To the above various forms of insensible motion thus caused, we have to add sensible motion. On the production of this mode of force, more especially depends the possibility of all vital phenomena. It is, indeed, usual to regard the power of generating sensible motion, as confined to one out of the two organic sub-kingdoms; or, at any rate, as possessed by but few members of the other. On looking closer into the matter, however, we see that plant-life as well as animal-life, is universally accompanied by certain manifestations of this power; and that plant-life could not otherwise continue.

Through the humblest, as well as through the highest, vegetal organisms, there are ever going on certain re-distributions of matter. In protophytes the microscope shows us an internal transposition of parts, which when not active enough to be immediately visible, is proved to exist by the changes of arrangement that become manifest in the course of hours and days. In the individual cells of many higher plants, an active movement among the contained granules may be witnessed. And well-developed cryptogams in common with all phanerogams, exhibit this genesis of mechanical motion still more conspicuously in the circulation of sap. It might, indeed, be concluded *à priori*, that through plants displaying much differentiation of parts, an internal movement must be going on; since, without it, the mutual dependence of organs having unlike functions would seem impossible. Besides these motions of fluids kept up internally, plants, especially of the lower orders, are able to move their external parts in relation to each other, and also to move about from place to place. Illustrations in abundance will occur to all students of recent Natural History—such illustrations as the active locomotion of the zoospores of many Algæ, the rhythmical bendings of the *Oscillatoriæ*, the rambling progression of the *Diatomaceæ*. In fact many of these smallest vegetals, and many of the larger ones in their early stages, display a mechanical activity not distinguishable from that of the simplest animals. Among well-organized plants, which are never locomotive in their adult states, we still not unfrequently meet with relative motions of parts. To such familiar cases as those of the Sensitive plant and the Venus' fly-trap, many others may be added. When its base is irritated, the stamen of the Berberry flower leans over and touches the pistil. If the stamens of the common wild *Cistus* be gently brushed with the finger, they spread themselves—bending away from the seed-vessel. And some of the orchid-flowers, as Mr Darwin has recently shown, shoot out masses of pollen on to the entering bee, when its trunk is thrust down in search of honey.

Though the power of moving is not, as we see, a characteristic of animals alone, yet in them, considered as a class, it is manifested to an extent so marked, as practically to become one of their distinctive characters—indeed, we may say, their most distinctive character. For it is by their immensely greater ability to generate mechanical motion, that animals are enabled to perform those actions which constitute their visible lives; and it is by their immensely greater ability to generate mechanical motion, that the higher orders of animals are most obviously distinguished from the lower orders. Though, on remembering the seemingly active movements of infusoria, some will perhaps question this last-named contrast; yet, on comparing the quantities of matter propelled through given spaces in given times, they will see that the momentum evolved is far less in the protozoa than in the telcozoa. These sensible motions of animals are effected by various organs under various stimuli. In the humblest forms, and even in some of the more developed ones which inhabit the water, locomotion results from the vibrations of cilia: the contractility resides in these waving hairs that grow from the surface. Some of the *Acalephæ*, and their allies the Polypes, move when mechanically irritated: the long pendant tentacle of a *Physalia* is suddenly drawn up if touched; and, as well as its tentacles, the whole body of a *Hydra* collapses if roughly handled, or jarred by some shock in its neighbourhood. In all the higher animals however, and to a smaller degree in many of the lower, sensible motion is generated by a special tissue, under the special excitement of a neural discharge. Though it is not strictly true that such animals show no sensible motions otherwise caused; since all of them have certain ciliated membranes, and since the circulation of fluid in them is partially due to osmotic and capillary actions; yet, generally speaking, we may say that their movements are effected only by muscles that contract only through the agency of nerves.

What special transformations of force generate these various mechanical changes, we do not, in most cases, know. Those re-distributions of fluid, with the alterations of form sometimes caused by them, that result from osmose, are not, indeed, quite incomprehensible. Certain motions of plants which, like those of the "animated oat," follow contact with water, are easily interpreted; as are also such other vegetal motions as those of the Touch-me-not, the Squirting Cucumber, and the *Carpobolus*. But we have as yet no clue to the mode in which molecular movement is transformed into the movement of masses, in animals. We cannot refer to known causes the rhythmical action of a Medusa's disc, or that slow decrease of bulk that spreads throughout the mass of an *Alcyonium*, when one of its component individuals has been irritated. Nor are we any better able to say how the insensible motion transmitted through a nerve, gives rise to sensible motion in a muscle. It is true that Science has given to Art, several methods of changing insensible into sensible motion. By applying heat to water we vaporize it; and the movement of its expanding vapour, we transfer to solid matter; but it is clear that the genesis of muscular movement is in no way analogous to this. The force evolved during chemical transformations in a galvanic battery, we communicate to a soft iron magnet through a wire coiled round it; and it would be quite possible, by placing near to each other several magnets thus excited, to obtain, through the attraction of each for its neighbours, an accumulated movement made up of their separate movements, and thus to mechanically imitate a muscular contraction; but from what we know of organic matter, and the structure of muscle, there is no reason to suppose that anything analogous to this takes place in it. We can, however, through one kind of molecular change, produce sensible changes of aggregation such as possibly might, when occurring in organic substance, cause sensible motion in it: I refer to allotropic change. Sulphur, for example, assumes different crystalline and non-crystalline forms at different temperatures; and may be made to pass backwards and forwards from one form to another, by slight variations of temperature: undergoing each time an alteration of bulk. We know that this allotropism, or rather its analogue isomerism, prevails among colloids — inorganic and organic. We also know that some of these metamorphoses among colloids, are accompanied by visible re-arrangements: instance hydrated silicic acid, which, after passing from its soluble state to the state of an insoluble jelly, begins, in a few days, to contract, and to give out part of its contained water. Now, considering that such isomeric changes of organic as well as inorganic colloids, are often very rapidly produced by very slight causes, it seems not impossible that some of the colloids constituting muscle, may be thus changed by a nervous discharge—resuming their previous condition when the discharge ceases. And it is conceivable that by structural

follows from the persistence of force, that each portion of mechanical or other energy which an organism exerts, implies the transformation of as much organic matter as contained this energy in a latent state. And on the other hand, it follows from the persistence of force that no such transformation of organic matter containing this latent energy can take place, without the energy being in one shape or other manifested.

CHAPTER IV.*

PROXIMATE DEFINITION OF LIFE.

§ 24. To those who accept the general doctrine of Evolution, it needs scarcely be pointed out that classifications are subjective conceptions, which have no absolute demarcations in Nature corresponding to them. They are appliances by which we limit and arrange the matters under investigation; and so facilitate our thinking. Consequently, when we attempt to define anything complex, or make a generalization of facts other than the most simple, we can scarcely ever avoid including more than we intended, or leaving out something that should be taken in. Thus it happens that on seeking a definition of Life, we have great difficulty in finding one that is neither more nor less than sufficient. Let us look at a few of the most tenable definitions that have been given. While recognizing the respects in which they are defective, we shall see what requirements a more complete one must fulfil.

* This chapter and the following two chapters originally appeared in Part III. of the *Principles of Psychology*: forming a preliminary which, though indispensable to the argument there developed, was somewhat parenthetical. Having now to deal with the general science of Biology before the more special one of Psychology, it becomes possible to transfer these chapters to their proper place. They have been carefully revised.

Schelling said that Life is the tendency to individuation. This formula, until studied, conveys little meaning. But it needs only to consider it as illustrated by the facts of development, or by the contrasts between lower and higher forms of life, to recognize its value; especially in respect of comprehensiveness. As before shown, however, (*First Principles*, § 56), it is objectionable, partly on the ground that it refers, not so much to the functional changes constituting Life, as to the structural changes of those aggregations of matter which manifest Life; and partly on the ground that it includes under the idea Life, much that we usually exclude from it: for instance—crystallization.

The definition of Richerand, — "Life is a collection of phenomena which succeed each other during a limited time in an organized body,"—is liable to the fatal criticism, that it equally applies to the decay which goes on after death. For this, too, is "a collection of phenomena which succeed each other during a limited time in an organized body."

"Life," according to De Blainville, "is the two-fold internal movement of composition and decomposition, at once general and continuous." This conception is in some respects too narrow, and in other respects too wide. On the one hand, while it expresses what physiologists distinguish as vegetative life, it excludes those nervous and muscular functions which form the most conspicuous and distinctive classes of vital phenomena. On the other hand, it describes not only the integrating and disintegrating processes going on in a living body, but it equally well describes those going on in a galvanic battery; which also exhibits a "two-fold internal movement of composition and decomposition, at once general and continuous."

Elsewhere, I have myself proposed to define Life as "the co-ordination of actions;"* and I still incline towards this definition as one answering to the facts with tolerable precision.

* See *Westminster Review* for April, 1852.—Art. IV. "A Theory of Population."

It includes all organic changes, alike of the viscera, the limbs, and the brain. It excludes the great mass of inorganic changes; which display little or no co-ordination. By making co-ordination the specific characteristic of vitality, it involves the truths, that an arrest of co-ordination is death, and that imperfect co-ordination is disease. Moreover, it harmonizes with our ordinary ideas of life in its different gradations: seeing that the organisms which we rank as low in their degree of life, are those which display but little co-ordination of actions; and seeing that from these up to man, the recognized increase in degree of life corresponds with an increase in the extent and complexity of co-ordination. But, like the others, this definition includes too much; for it may be said of the Solar System, with its regularly-recurring movements and its self-balancing perturbations, that it, also, exhibits co-ordination of actions. And however plausibly it may be argued that, in the abstract, the motions of the planets and satellites are as properly comprehended in the idea of life, as the changes going on in a motionless, unsensitive seed; yet, it must be admitted that they are foreign to that idea as commonly received, and as here to be formulated.

It remains to add the definition since suggested by Mr G. H. Lewes—"Life is a series of definite and successive changes, both of structure and composition, which take place within an individual without destroying its identity." The last fact which this statement has the merit of bringing into view—the persistence of a living organism as a whole, in spite of the continuous removal and replacement of its parts—is important. But otherwise it may be argued, that since changes of structure and composition, though probably the *causes* of muscular and nervous actions, are not the muscular and nervous actions themselves, the definition excludes the more visible movements with which our idea of life is most associated; and further, that in describing vital changes as *a series*, it scarcely includes the fact that many of them, as

Nutrition, Circulation, Respiration, and Secretion, in their many subdivisions, go on simultaneously.

Thus, however well each of these definitions expresses the phenomena of life under some of its aspects, no one of them is more than approximately true. It may turn out, that to find a formula which will bear every test is impossible. Meanwhile, it is possible to frame a more adequate formula than any of the foregoing. As we shall presently find, these all omit an essential peculiarity of vital changes in general—a peculiarity which, perhaps more than any other, distinguishes them from non-vital changes. Before specifying this peculiarity, however, it will be well to trace our way, step by step, to as complete an idea of Life as may be reached from our present stand-point: by doing which, we shall both see the necessity for each limitation as it is made, and ultimately be led to feel the need for a further limitation

And here, as the best mode of determining what are those general characteristics which distinguish vitality from non-vitality, we shall do well to compare the two most unlike kinds of vitality, and see in what they agree. Manifestly, that which is essential to Life must be that which is common to Life of all orders. And manifestly, that which is common to all forms of Life, will most readily be seen on contrasting those forms of Life which have the least in common, or are the most unlike.*

§ 25. Choosing assimilation, then, for our example of bodily life, and reasoning for our example of that life known as intelligence; it is first to be observed, that they are both processes of change. Without change, food cannot be taken into the blood nor transformed into tissue: without

* This paragraph replaces a sentence that, in *The Principles of Psychology*, referred to a preceding chapter on "Method;" in which the mode of procedure here indicated, was set forth as a mode to be systematically pursued in the choice of hypotheses. Should opportunity ever permit, this chapter on Method will be embodied, along with other matter on the same topic, in a General Introduction to *First Principles*.

change, there can be no getting from premisses to conclusion. And it is this conspicuous manifestation of change, which forms the substratum of our idea of Life in general. Doubtless we see innumerable changes to which no notion of vitality attaches: inorganic bodies are ever undergoing changes of temperature, changes of colour, changes of aggregation. But it will be admitted that the great majority of the phenomena displayed by inorganic bodies, are statical and not dynamical; that the modifications of inorganic bodies are mostly slow and unobtrusive; that on the one hand, when we see sudden movements in inorganic bodies, we are apt to assume living agency, and on the other hand, when we see no movements in organic bodies, we are apt to assume death. From all which considerations it is manifest, that be the requisite qualifications what they may, a definition of Life must be a definition of some kind of change or changes.

On further comparing assimilation and reasoning, with a view of seeing in what respect the change displayed in both differs from non-vital change, we find that it differs in being not simple change, but change made up of *successive* changes. The transformation of food into tissue, involves mastication, deglutition, chymification, chylification, absorption, and those various actions gone through after the lacteal ducts have poured their contents into the blood. Carrying on an argument necessitates a long chain of states of consciousness; each implying a change of the preceding state. Inorganic changes, however, do not in any considerable degree exhibit this peculiarity. It is true that from meteorologic causes, inanimate objects are daily, sometimes hourly, undergoing modifications of temperature, of bulk, of hygrometric and electric condition. Not only, however, do these modifications lack that conspicuousness and that rapidity of succession which vital ones possess, but vital ones form an *additional* series. Living as well as not-living bodies are affected by atmospheric influences; and beyond the changes which these produce, living bodies exhibit other changes, more numerous and more marked. So that though organic change is not rigorously distinguished from inorganic change by presenting successive phases—though some inanimate objects, as watches, display phases of change both quick and numerous—though all objects are ever undergoing change of some kind, visible or invisible—though there is scarcely any object which does not, in the lapse of time, undergo a considerable amount of change that is fairly divisible into phases; yet, vital change so greatly exceeds other change in its display of varying phases, that we may consider this as practically one of its characteristics. Life, then, as thus roughly differentiated, may be regarded as change presenting successive phases; or otherwise, as a series of changes. And it should be observed, as a fact in harmony with this conception, that the higher the life the more conspicuous the variations. On comparing inferior with superior organisms, these last will be seen to display more rapid changes, or a more lengthened series of them, or both.

Contemplating afresh our two typical phenomena, we may see that vital change is further distinguished from non-vital change, by being made up of many *simultaneous* changes. Assimilation is not simply a series of actions, but includes many actions going on together. During mastication the stomach is busy with the food already swallowed; on which it is both pouring out solvent fluids and expending muscular efforts. While the stomach is still active, the intestines are performing their secretive, contractile, and absorbent functions; and at the same time that one meal is being digested, the nutriment obtained from a previous meal is undergoing that transformation into tissue which constitutes the final act of assimilation. So also is it, in a certain sense, with mental changes. Though the states of consciousness which make up an argument occur in series, yet, as each of these states is complex—implies the simultaneous excitement of those many faculties by which the perception of any object or relation has been effected; it is obvious that each such change in

mostly mechanical actions that are to a great degree similar; and in this respect widely differ from the actions at any moment taking place in an organism: which not only belong to the several classes, mechanical, chemical, thermal, electric, but present under each of these classes, innumerable unlike actions. Even where life is nearly simulated, as by the working of a steam-engine, we may see that considerable as is the number of simultaneous changes, and rapid as are the successive ones, the regularity with which they soon recur in the same order and degree, renders them unlike those varied changes exhibited by a living creature. Still, it will be found that this peculiarity, like the foregoing ones, does not divide the two classes of changes with precision; inasmuch as there are inanimate things which exhibit considerable heterogeneity of change: for instance, a cloud. The variations of state which this undergoes, both simultaneous and successive, are many and quick; and they differ widely from each other both in quality and quantity. At the same instant there may occur in a cloud, change of position, change of form, change of size, change of density, change of colour, change of temperature, change of electric state; and these several kinds of change are continuously displayed in different degrees and combinations. Yet notwithstanding this, when we consider that very few inorganic objects manifest heterogeneity of change in a marked manner, while all organic objects manifest it; and further, that in ascending from low to high forms of life, we meet with an increasing variety in the kinds and amounts of changes displayed; we see that there is here a further leading distinction between organic and inorganic actions. According to this modified conception, then, Life is made up of heterogeneous changes both simultaneous and successive.

If now we look for some point of agreement between the assimilative and logical processes, by which they are distinguished from those inorganic processes that are most like them in the heterogeneity of the simultaneous and successive changes they comprise, we discover that they are distinguished by the *combination* subsisting among their constituent changes. The acts that make up digestion are mutually dependent. Those composing a train of reasoning are in close connection. And generally, it is to be remarked of vital changes, that each is made possible by all, and all are affected by each. Respiration, circulation, absorption, secretion, in their many sub-divisions, are bound up together. Muscular contraction involves chemical change, change of temperature, and change in the excretions. Active thought influences the operations of the stomach, of the heart, of the kidneys. But we miss this union among inorganic processes. Life-like as may seem the action of a volcano in respect of the heterogeneity of its many simultaneous and successive changes, it is not life-like in respect of their combination. Though the chemical, mechanical, thermal, and electric phenomena exhibited, have some inter-dependence; yet the emission of stones, mud, lava, flame, ashes, smoke, steam, usually takes place irregularly in quantity, order, intervals, and mode of conjunction. Even here, however, it cannot be said that inanimate things present no parallels to animate ones. A glacier may be instanced as showing nearly as much combination in its changes as a plant of the lowest organization. It is ever growing and ever decaying; and the rates of its composition and decomposition preserve a tolerably constant ratio. It moves; and its motion is in immediate dependence on its thawing. It emits a torrent of water, which, in common with its motion, undergoes annual variations, as plants do. During part of the year the surface melts and freezes alternately; and on these changes are dependent the variations in movement, and in efflux of water. Thus we have growth, decay, changes of temperature, changes of consistence, changes of velocity changes of excretion, all going on in connexion; and it may be as truly said of a glacier as of an animal, that by ceaseless integration and disintegration it gradually undergoes an entire change of substance without losing its individuality.

This exceptional instance, however, will scarcely be held to obscure that broad distinction from inorganic processes, which organic processes derive from the combination among their constituent changes. And the reality of this distinction becomes yet more manifest when we find that, in common with previous ones, it not only marks off the living from the not-living, but also things which live little from things which live much. For while the changes going on in a plant or a zoophyte are so imperfectly combined that they can continue after it has been divided into two or more pieces, the combination among the changes going on in a mammal is so close that no part cut off from the rest can live, and any considerable disturbance of one function causes a cessation of the others. Life, therefore, as we now regard it, is a combination of heterogeneous changes, both simultaneous and successive.

Once more looking for a characteristic common to these two kinds of vital action, we perceive that the combinations of heterogeneous changes which constitute them, differ from the few combinations which they otherwise resemble, in respect of *definiteness*. The associated changes going on in a glacier, admit of indefinite variation. Under a conceivable alteration of climate, its thawing and its progression may be stopped for myriads of years, without disabling it from again displaying these phenomena under appropriate conditions. By a geological convulsion, its motion may be arrested without an arrest of its thawing; or by an increase in the inclination of the surface it slides over, its motion may be accelerated without accelerating its rate of dissolution. Other things remaining the same, a more rapid deposit of snow may cause an indefinite increase of bulk; or, conversely, the accretion may entirely cease, and yet all the other actions continue until the mass disappears. Here, then, the combination has none of that definiteness which, in a plant, marks the mutual dependence of assimilation, respiration, and circulation; much less has it that definiteness seen in the mutual dependence of the chief animal functions: no one of which can be varied without varying the rest: no one of which can go on unless the rest go on. It is this definiteness of combination which distinguishes the changes occurring in a living body from those occurring in a dead one. Decomposition exhibits both simultaneous and successive changes, which are to some extent heterogeneous, and in a sense combined; but they are not combined in a definite manner. They vary according as the surrounding medium is air, water, or earth. They alter in nature with the temperature. If the local conditions are unlike, they progress differently in different parts of the mass, without mutual influence. They may end in producing gases, or adipocire, or the dry substance of which mummies consist. They may occupy a few days, or thousands of years. Thus, neither in their simultaneous nor in their successive changes, do dead bodies display that definiteness of combination which characterizes living ones. It is true that in some inferior creatures the cycle of successive changes admits of a certain indefiniteness—that it may be apparently suspended for a long period by desiccation or freezing; and may afterwards go on as though there had been no breach in its continuity. But the circumstance that only a low order of life permits the cycle of its changes to be thus modified, serves but to suggest that, like the previous characteristics, this characteristic of definiteness in its combined changes, distinguishes high vitality from low vitality, as it distinguishes low vitality from inorganic processes. Hence, our formula as further amended reads thus:—Life is a definite combination of heterogeneous changes, both simultaneous and successive.

Finally, we shall still better express the facts, if, instead of saying *a* definite combination of heterogeneous changes, we say *the* definite combination of heterogeneous changes. As it at present stands, the definition is defective both in allowing that there may be *other* definite combinations of heterogeneous changes, and in directing attention to the heterogeneous changes rather than to the definiteness of their combination. Just as it is not so much its chemical elements which constitute an organism, as it is the arrangement of them into special tissues and organs; so it is not so much its heterogeneous changes which constitute Life, as it is the definite combination of them. Observe what it is that ceases when life ceases. In a dead body there are going on heterogeneous changes, both simultaneous and successive. What then has disappeared? The definite combination has disappeared. Mark, too, that however heterogeneous the simultaneous and successive changes exhibited by an inorganic object, as a volcano, we much less tend to think of it as living, than we do a watch or a steam-engine, which, though displaying homogeneous changes, displays them definitely combined. So dominant an element is this in our idea of Life, that even when an object is motionless, yet, if its parts be definitely combined, we conclude either that it has had life, or has been made by something having life. Thus then, we conclude that Life is—*the* definite combination of heterogeneous changes, both simultaneous and successive.

§ 26. Such is the conception at which we arrive without changing our stand-point. It is, however, an incomplete conception. This ultimate formula (which is to a considerable extent identical with one above given—"the co-ordination of actions;" seeing that "definite combination" is synonymous with "co-ordination," and "changes both simultaneous and successive" are comprehended under the term "actions;" but which differs from it in specifying the fact, that the actions or changes are "heterogeneous")—this ultimate formula, I say, is after all but proximately correct. It is true that it does not fail by including the growth of a crystal; for the successive changes this implies cannot be called heterogeneous. It is true that the action of a galvanic battery is not comprised in it; since here, too, heterogeneity is not exhibited by the successive changes. It is true that by this same qualification the motions of the Solar System are excluded; as are also those of a watch and a steam-engine. It is true, moreover, that while, in virtue of their heterogeneity, the actions going on in a cloud, in a volcano, in a glacier, fulfil the definition; they fall short of it in lacking definiteness of combination. It is further true that this definiteness of combination, distinguishes the changes taking place in an organism during life, from those which commence at death. And beyond all this it is true that, as well as serving to mark off, more or less clearly, organic actions from inorganic actions, each member of the definition serves to mark off the actions constituting high vitality from those constituting low vitality; seeing that life is high in proportion to the number of successive changes occurring between birth and death; in proportion to the number of simultaneous changes; in proportion to the heterogeneity of the changes; in proportion to the combination subsisting among the changes; and in proportion to the definiteness of their combination. Nevertheless, answering though it does to so many requirements, this definition is essentially defective. It does not convey a complete idea of the thing contemplated. *The definite combination of heterogeneous changes, both simultaneous and successive,* is a formula which fails to call up an adequate conception. And it fails from omitting the most distinctive peculiarity — the peculiarity of which we have the most familiar experience, and with which our notion of Life is, more than with any other, associated. It remains now to supplement the definition by the addition of this peculiarity.

CHAPTER V.

THE CORRESPONDENCE BETWEEN LIFE AND ITS CIRCUMSTANCES.

§ 27. We habitually distinguish between a live object and a dead one, by observing whether a change which we make in the surrounding conditions, or one which Nature makes in them, is or is not followed by some perceptible change in the object. By discovering that certain things shrink when touched, or fly away when approached, or start when a noise is made, the child first roughly discriminates between the living and the not-living; and the man when in doubt whether an animal he is looking at is dead or not, stirs it with his stick; or if it be at a distance, shouts, or throws a stone at it. Vegetal and animal life are alike primarily recognized by this process. The tree that puts out leaves when the spring brings a change of temperature, the flower which opens and closes with the rising and setting of the sun, the plant that droops when the soil is dry, and re-erects itself when watered, are considered alive because of these induced changes; in common with the zoophyte which contracts on the passing of a cloud over the sun, the worm that comes to the surface when the ground is continuously shaken, and the hedgehog that rolls itself up when attacked.

Not only, however, do we habitually look for some response when an external stimulus is applied to a living organism, but we perceive a fitness in the response. Dead as well as living things display changes under certain changes of con-

Grouping together the cases first named, in which a particular change in the circumstances of an organism is followed by a particular change in it, and the cases last named, in which the constant actions occurring within an organism imply some constant actions occurring without it; we see that in both, the changes or processes displayed by a living body are specially related to the changes or processes in its environment. And here we have the needful supplement to our conception of Life. Adding this all-important characteristic, our conception of Life becomes—The definite combination of heterogeneous changes, both simultaneous and successive, *in correspondence with external co-existences and sequences.* That the full significance of this addition may be seen, it will be necessary to glance at the correspondence under some of its leading aspects.*

§ 28. Neglecting minor requirements, tne actions going

* Speaking of "the general idea of *life*," M. Comte says:—"Cette idée suppose, en effet, non-seulement celle d'un être organisé de manière à comporter l'état vital, mais aussi celle, non moins indispensable, d'un certain ensemble d'influences extérieures propres à son accomplissement. Une telle harmonie entre l'être vivant et le *milieu* correspondant, caractérise évidemment la condition fondamentale de la vie." Commenting on de Blainville's definition of life, which he adopts, he says:—"Cette lumineuse définition ne me paraît laisser rien d'important à désirer, si ce n'est une indication plus directe et plus explicite de ces deux conditions fondamentales co-relatives, nécessairement inséparables de l'état vivant, un *organisme* déterminé et un *milieu* convenable." It is strange that M. Comte should have thus recognized the necessity of a harmony between an organism and its environment, as a *condition* essential to life, and should not have seen that the continuous maintenance of such inner actions as will counterbalance outer actions, *constitutes* life. It is the more strange that he should have been so near this truth and yet missed it, since, besides his wide range of thought, M. Comte is often remarkable for his clear intuitions. Lest by saying this, I should deepen a misconception into which some have fallen, let me take the opportunity of stating, that though I believe some of M. Comte's minor generalizations to be true, and though I recognize the profundity of many incidental observations he makes, I by no means accept his system. Those general doctrines in which I agree with him, are those which he holds in common with sundry other thinkers. With all those general doctrines which are distinctive of his philosophy, I disagree—with all those at least that I have definite knowledge of; for beyond the first half of his "Course of Positive Philosophy," I know his opinions only by hearsay.

stance in the environment capable of transformation into its own tissue; but that the introduction of these masses into its stomach, shall be followed by the secretion of a solvent fluid that will reduce them to a fit state for absorption. Special outer properties must be met by special inner properties.

When, from the process by which food is digested, we turn to the processes by which it is seized, we perceive the same general truth. The stinging and contractile power of a polype's tentacle, correspond to the sensitiveness and strength of the creatures serving it for prey. Unless that external change which brings one of these creatures in contact with the tentacle, were quickly followed by those internal changes which result in the coiling and drawing up of the tentacle, the polype would die of inanition. The fundamental processes of integration and disintegration within it, would get out of correspondence with the agencies and processes without it; and the life would cease.

Similarly, it may be shown that when the creature becomes so large that its tissue cannot be efficiently supplied with nutriment by mere absorption through its limiting membranes, or duly oxygenated by contact with the fluid that bathes its surface, there arises a necessity for a circulatory system by which nutriment and oxygen may be distributed throughout the mass; and the functions of this system, being subsidiary to the two primary functions, form links in the correspondence between internal and external actions. The like is obviously true of all those subordinate functions, secretory and excretory, that facilitate oxidation and assimilation—functions in which we may trace, both co-temporaneous changes answering to co-existences in the environment, and successive changes answering to those changes of composition, of temperature, of light, of moisture, of pressure, which the environment undergoes.

Ascending from the visceral actions to the muscular and nervous actions, we find the correspondence displayed in a manner still more obvious. Every act of locomotion implies the expenditure of certain internal mechanical forces, adapted in amounts and directions to balance or out-balance certain external ones. The recognition of an object is impossible without a harmony between the changes constituting perception, and particular properties co-existing in the environment. Escape from enemies supposes motions within the organism, related in kind and rapidity to motions without it. Destruction of prey requires a particular combination of subjective actions, fitted in degree and succession to overcome a group of objective ones. And so with those countless automatic processes exemplified in works on animal instinct.

In the highest order of vital changes, the same fact is equally manifest. The empirical generalization that guides the farmer in his rotation of crops, serves to bring his actions into concord with certain of the actions going on in plants and soil. The rational deductions of the educated navigator who calculates his position at sea, constitute a series of mental acts by which his proceedings are conformed to surrounding circumstances. Alike in the simplest inferences of the child, and the most complex ones of the man of science, we find a correspondence between simultaneous and successive changes in the organism, and co-existences and sequences in its environment.

§ 29. This general formula, which thus includes the lowest vegetal processes as well as the highest manifestations of human intelligence, will perhaps call forth some criticisms which it is desirable here to meet.

It may be thought that there are still a few inorganic actions included in the definition; as for example that displayed by the mis-named storm-glass. The feathery crystallization which, on a certain change of temperature, takes place in the solution contained by this instrument, and which afterwards dissolves to reappear in new forms under new conditions, may be held to present simultaneous and successive changes that are to some extent heterogeneous, that occur with some definiteness of combination, and, above all, occur in correspondence with external changes. In this case vegetal life is simulated to a considerable extent; but it is *merely* simulated. The relation between the phenomena occurring in the storm-glass and in the atmosphere respectively, is really not a correspondence at all, in the proper sense of the word. Outside there is a certain change; inside there is a change of atomic arrangement. Outside there is another certain change; inside there is another change of atomic arrangement. But subtle as is the dependence of each internal upon each external change, the connexion between them does not, in the abstract, differ from the connexion between the motion of a straw and the motion of the wind that disturbs it. In either case a change produces a change, and there it ends. The alteration wrought by some environing agency on an inanimate object, does not tend to induce in it a secondary alteration, that anticipates some secondary alteration in the environment. But in every living body there is a tendency towards secondary alterations of this nature; and it is in their production that the correspondence consists. The difference may be best expressed by symbols. Let A be a change in the environment; and B some resulting change in an inorganic mass. Then A having produced B, the action ceases. Though the change A in the environment, is followed by some consequent change *a* in it; no parallel sequence in the inorganic mass simultaneously generates in it some change *b* that has reference to the change *a*. But if we take a living body of the requisite organization, and let the change A impress on it some change C; then, while in the environment A is occasioning *a*, in the living body C will be occasioning *c*: of which *a* and *c* will show a certain concord in time, place, or intensity. And while it is in the continuous production of such concords or correspondences that Life consists, it is *by* the continuous production of them that Life is maintained.

The further criticism that may be expected, concerns our tain verbal imperfections in the definition, which it seems impossible to avoid. It may be fairly urged that the word *correspondence* will not include, without straining, the various relations to be expressed by it. It may be asked :—How can the continuous *processes* of assimilation and respiration, correspond with the *co-existence* of food and oxygen in the environment? or again :—How can the act of secreting some defensive fluid, correspond with some external danger which may never occur? or again :—How can the *dynamical* phenomena constituting perception, correspond with the *statical* phenomena of the solid body perceived? The only reply to these questions, is, that we have no word sufficiently general to comprehend all forms of this relation between the organism and its medium, and yet sufficiently specific to convey an adequate idea of the relation; and that the word *correspondence* seems the least objectionable. The fact to be expressed in all cases, is, that certain changes, continuous or discontinuous, in the organism, are connected after such a manner that, in their amounts, or variations, or periods of occurrence, or modes of succession, they have a reference to external actions, constant or serial, actual or potential—a reference such that a definite relation among any members of the one group, implies a definite relation among certain members of the other group; and the word *correspondence* appears the best fitted to express this fact.

§ 30. The presentation of the phenomena under this general form, suggests how our definition of Life may be reduced to its most abstract shape; and perhaps its best shape. By regarding the respective elements of the definition as relations, we avoid both the circumlocution and the verbal inaccuracy; and that we may so regard them with propriety is obvious. If a creature's rate of assimilation is increased in consequence of a decrease of temperature in the environment; it is that the relation between the food consumed and heat produced, is so re-adjusted by multiplying both its members, that the altered relation in the surrounding medium between the quantity of heat absorbed from, and radiated to, bodies of a given temperature, is counterbalanced. If a sound or a scent wafted to it on the breeze, prompts the stag to dart away from the deer-stalker; it is that there exists in its neighbourhood a relation between a certain sensible property and certain actions dangerous to the stag, while in its organism there exists an adapted relation between the impression this sensible property produces, and the actions by which danger is escaped. If inquiry has led the chemist to a law, enabling him to tell how much of any one element will combine with so much of another; it is that there has been established in him specific mental relations, which accord with specific chemical relations in the things around. Seeing, then, that in all cases we may consider the external phenomena as simply in relation, and the internal phenomena also as simply in relation; the broadest and most complete definition of Life will be—*The continuous adjustment of internal relations to external relations.**

While it is simpler, this modified formula has the further advantage of being somewhat more comprehensive. To say that it includes not only those definite combinations of simultaneous and successive changes in an organism, which correspond to co-existences and sequences in the environment, but also those structural arrangements which *enable* the organism to adapt its actions to actions in the environment, may perhaps be going too far; for though these structural arrangements present internal relations adjusted to external relations, yet the *continuous adjustment* of relations can scarcely be held to include a *fixed adjustment* already made. Clearly, Life, which is made up of *dynamical* phenomena, cannot be defined in terms that shall at the same time define the apparatus manifesting it, which presents only *statical* phenomena. But while this antithesis serves to remind us that the fundamental distinction between the organism and

* In further elucidation of this general doctrine, see *First Principles*, § 25.

CHAPTER VI.

THE DEGREE OF LIFE VARIES AS THE DEGREE OF CORRESPONDENCE.

§ 31. ALREADY it has been shown respecting each other qualification included in the foregoing definition, that the life is high in proportion as that qualification is well fulfilled; and it is now to be remarked, that the same thing is especially true respecting this last qualification—the correspondence between internal and external relations. It is manifest *à priori*, that since changes in the physical state of the environment, as also those mechanical actions and those variations of available food which occur in it, are liable to stop the processes going on in the organism; and since the adaptive changes in the organism have the effects of directly or indirectly counterbalancing these changes in the environment; it follows that the life of the organism will be short or long, low or high, according to the extent to which changes in the environment are met by corresponding changes in the organism. Allowing a margin for perturbations, the life will continue only while the correspondence continues; the completeness of the life will be proportionate to the completeness of the correspondence; and the life will be perfect only when the correspondence is perfect. Not to dwell in general statements, however, let us contemplate this truth under its concrete aspects.

§ 32. *In* life of the lowest order, we find that only the most prevalent coexistences and sequences in the environment, have any simultaneous and successive changes answering to them in the organism. A plant's vital processes display adjustment solely to the continuous coëxistence of certain elements and forces surrounding its roots and leaves; and vary only with the variations produced in these elements and forces by the sun—are unaffected by the countless mechanical and other changes occurring around; save when accidentally arrested by these. The life of a worm is made up of actions referring almost exclusively to the tangible properties of adjacent things. All those visible and audible changes which happen near it, and are connected with other changes that may presently destroy it, pass unrecognized—produce in it no adapted changes: its only adjustment of internal relations to external relations of this order, is seen when it escapes to the surface on feeling the vibrations produced by an approaching mole. Adjusted as are the proceedings of a bird, to a far greater number of coexistences and sequences in the environment, cognizable by sight, hearing, scent, and their combinations; and numerous as are the dangers it shuns and the needs it fulfils, in virtue of this extensive correspondence; it exhibits no such actions as those by which a human being counterbalances variations in temperature and supply of food, consequent on the seasons. And when we see the plant eaten, the worm trodden on, the bird dead from starvation; we see alike that the death is an arrest of such correspondence as existed; that it occurred when there was some change in the environment to which the organism made no answering change; and that thus, both in shortness and simplicity, the life was incomplete in proportion as the correspondence was incomplete. Progress towards more prolonged and higher life, evidently implies an ability to respond to less general coexistences and sequences. Each step upwards must consist in adding to the previously-adjusted relations which the organism exhibits, some further relation parallel to a further relation in the environment. And the greater correspondence thus established, must, other things equal, show itself both in greater complexity of life, and greater length of life—a truth which will be duly realized on remembering that enormous mortality which prevails among lowly-organized creatures, and that gradual increase of longevity and diminution of fertility which we meet with on ascending to creatures of higher and higher development.

It must, however, be remarked, that while length and complexity of life are, to a great extent, associated—while a more extended correspondence in the successive changes, commonly implies increased correspondence in the simultaneous changes; yet it is not uniformly so. Between the two great divisions of life—animal and vegetal—this contrast by no means holds. A tree may live a thousand years, though the simultaneous changes going on in it answer only to the few chemical affinities in the air and the earth, and though its serial changes answer only to those of day and night, of the weather and the seasons. A tortoise, which exhibits in a given time nothing like the number of internal actions adjusted to external ones, that are exhibited by a dog, yet lives far longer. The tree by its massive trunk, and the tortoise by its hard carapace, are saved the necessity of responding to those many surrounding mechanical actions which organisms not thus protected must respond to or die; or rather—the tree and the tortoise display in their structures, certain simple statical relations adapted to meet countless dynamical relations external to them. But notwithstanding the qualifications suggested by such cases, it needs but to compare a microscopic fungus with an oak, an animalcule with a shark, a mouse with a man, to recognize the fact that this increasing correspondence of its changes with those of the environment, which characterizes progressing life, habitually shows itself at the same time in continuity and in complication.

Even were not the connexion between length of life and complexity of life thus conspicuous, it would still be true that the degree of life varies with the degree of correspondence. For if the lengthened existence of a tree be looked upon as tantamount to a considerable degree of life; then it must be admitted that its lengthened display of correspondences is tantamount to a considerable degree of correspondence. If otherwise it be held, that notwithstanding its much shorter existence, a dog must rank above a tortoise in degree of life, because of its superior activity; then it is implied that its life is higher, because its simultaneous and successive changes are more complex and more rapid—because the correspondence is greater. And since we regard as the highest life, that which, like our own, shows great complexity in the correspondences, great rapidity in the succession of them, and great length in the series of them; the equivalence between degree of life and degree of correspondence, is unquestionable.

§ 33. In further elucidation of this general truth, and especially in explanation of the irregularities just referred to, it requires to be observed, that as the life becomes higher the environment itself becomes more complex. Though, literally, the environment means all surrounding space with the coexistences and sequences contained in it; yet, practically, it often means but a small part of this. The environment of an entozoon, can scarcely be said to extend beyond the body of the animal in which the entozoon lives. That of a fresh-water alga is, virtually, limited to the ditch inhabited by the alga. And understanding the term in this restricted sense, we shall see that the superior organisms inhabit the more complicated environments.

Thus, contrasted with that found on land, the lower life is that found in the sea; and it has the simpler environment. Marine creatures are affected by a smaller number of coexistences and sequences than terrestrial ones. Being very nearly of the same specific gravity as the surrounding medium, they have to contend with less various mechanical actions. The zoophyte rooted to a stone, and the acalephe passively borne along in the current, need to undergo no internal changes such as those by which the caterpillar meets the varying effects of gravitation, while creeping over and under the leaves. Again, the sea is liable to none of those extreme and rapid alterations of temperature which the air suffers. Night and day produce no appreciable modifications in it; and it is comparatively little affected by the seasons. Thus its contained fauna show no marked correspondences similar to those by which air-breathing creatures counterbalance thermal changes. Further, in respect to the supply of nutriment the conditions are more simple. The lower tribes of animals inhabiting the water, like the plants inhabiting the air, have their food brought to them. The same current which brings oxygen to the oyster, also brings it the microscopic organisms on which it lives: the disintegrating matter and the matter to be integrated, coexist under the simplest relation. It is otherwise with land animals. The oxygen is everywhere; but that which is needed to neutralize its action is not everywhere: it has to be sought; and the conditions under which it is to be obtained are more or less complex. So too with that liquid by the agency of which the vital processes are carried on. To marine creatures, water is ever present, and by the lowest is passively absorbed; but to most creatures living on the earth and in the air, it is made available only through those nervous changes constituting perception, and those muscular ones by which drinking is effected. Similarly, the contrast might be continued with respect to the electric and hygrometric variations; and the greater multiplicity of optical and acoustic phenomena with which terrestrial life is surrounded. And tracing upwards from the amphibia the widening extent and complexity which the environment, as practically considered, assumes—observing further how increasing heterogeneity in the flora and fauna of the globe, itself progressively complicates the environment of each species of organism—it might finally be shown that the same general truth is displayed in the history of mankind: whose advance in civilization has been simultaneous with their advance from the less varied requirements of the torrid zone to the more varied requirements of the temperate zone; whose chief steps have been made in regions presenting a complicated physical geography; and who, in the course of their progress, have been adding to their physical environment a social environment that has been growing even more involved. Thus, speaking generally, it is clear that those relations in the environment to which relations in the organism must correspond, themselves increase in number and intricacy as the life assumes a higher form.

§ 34. To make yet more manifest the fact, that the degree of life varies as the degree of correspondence, I may here point out, that those other distinctions successively noted when contrasting vital changes with non-vital changes, are all implied in this last distinction—their correspondence with external coexistences and sequences. And to this may be added the supplementary fact, that the increasing fulfilment of those other distinctions which we found to accompany increasing life, is involved in the increasing fulfilment of this last distinction. To descend to particulars:—We saw that living organisms are characterized by successive changes; and that as the life becomes higher, the successive changes become more numerous. Well, the environment is full of successive changes, both positive and relative; and the greater the correspondence, the greater the number of successive changes an organism must display. We saw that life presents simultaneous changes; and that the more elevated it is, the more marked the multiplicity of them. Well, besides countless phenomena of coexistence in the environment, there are often many changes occurring in it at the same moment; and hence increased correspondence with it, supposes an increased display of simultaneous changes in the organism. Similarly with the heterogeneity of the changes. In the environment the relations are very varied in their kinds; and hence, as the organic actions come more and more into correspondence with them, they also must become very varied in their kinds. So again is it, even with definiteness of combination. For though the inorganic bodies of which the environment mainly consists, do not present definitely-combined changes, yet they present definitely-combined properties; and though the minor meteorologic variations of the environment, do not show much definiteness of combination, yet those resulting from day and night and the seasons do. Add to which, that as the environment of each organism comprehends all those other organisms existing within its sphere of life—as the most important and most numerous surrounding changes with which each animal has to deal, are the definitely-combined changes exhibited by other animals, whether prey or enemies; it results that definiteness of combination is a general characteristic of the external changes with which internal ones have to correspond. Hence, increase of correspondence involves increased definiteness of combination. So that throughout, the correspondence of the internal relations with the external ones, is the essential thing; and all the special characteristics of the internal relations, are but the collateral results of this correspondence.

§ 35. As affording the simplest and most conclusive proof that the degree of life varies as the degree of correspondence, it remains to point out that perfect correspondence would be perfect life. Were there no changes in the environment but such as the organism had adapted changes to meet; and were it never to fail in the efficiency with which it met them; there would be eternal existence and universal knowledge. Death by natural decay, occurs because in old age the relations between assimilation, oxidation, and genesis of force going on in the organism, gradually fall out of correspondence with the relations between oxygen and food and absorption of heat by

undergo changes so comparatively numerous as to render the successiveness of their changes a marked characteristic. And it will follow *à priori*, as we found it to do *à posteriori*, that the organisms exhibiting Evolution in the highest degree, exhibit the longest or the most rapid successions of changes, or both. Again, it was shown that vital change is distinguished from non-vital change by being made up of many *simultaneous* changes; and also that creatures possessing high vitality are marked off from those possessing low vitality, by the far greater number of their simultaneous changes. Here too there is entire congruity. In *First Principles*, § 116, we reached the conclusion, that a force falling on any aggregate is divided into several forces; that when the aggregate consists of parts that are unlike, each part becomes a centre of unlike differentiations of the incident force; and that thus the multiplicity of such differentiations must increase with the multiplicity of the unlike parts. It follows necessarily, therefore, that organic aggregates, which as a class are distinguished from inorganic aggregates by the greater number of their unlike parts, must be also distinguished from them by the greater number of simultaneous changes they display; and further that the higher organic aggregates, having more numerous unlike parts than the lower, must undergo more numerous simultaneous changes. We next found that the changes occurring in living bodies, are contrasted with those occurring in other bodies, as being much more *heterogeneous*; and that the changes occurring in the superior living bodies, are similarly contrasted with those occurring in inferior ones. Well, heterogeneity of function is the correlate of heterogeneity of structure; and heterogeneity of structure is the leading distinction between organic and inorganic aggregates, as well as between the more highly organized and the more lowly organized. By reaction, an incident force must be rendered multiform in proportion to the multiformity of the aggregate on which it falls; and hence those most multiform aggregates which display in the highest degree the phenomena of Evolution structurally considered, must at the same time be aggregates which display in the highest degree the multiform actions which constitute Evolution functionally considered. These heterogeneous changes, exhibited simultaneously and in succession by a living organism, prove, on further inquiry, to be distinguished by their *combination* from certain non-vital changes which simulate them. Here, too, the parallelism is maintained. It was shown in § 56 of *First Principles*, that an essential characteristic of Evolution is the integration of parts, which accompanies their differentiation—an integration that is shown both in the consolidation of each part, and in the consolidation of all the parts into a whole. Now, manifestly, combination among the changes going on in different combined parts, must be proportionate to the degree of combination among these parts: the more mutually-dependent the parts, the more mutually-dependent must be their actions. Hence, animate bodies having greater co-ordination of parts than inanimate ones, must exhibit greater co-ordination of changes. And this greater co-ordination of their changes must not only distinguish organic from inorganic aggregates; but must, for the same reason, distinguish higher organisms from lower ones, as we found that it did. Yet once more, it was pointed out that the changes constituting Life, differ from other changes in the *definiteness* of their combination; and that a distinction like in kind, though less in degree, holds between the vital changes of superior creatures and those of inferior creatures. These, also, are contrasts in harmony with the contrasts disclosed by the analysis of Evolution. We saw (*First Principles*, §§ 54, 55) that during Evolution, there is an increase of definiteness as well as an increase of heterogeneity. We saw that the integration accompanying differentiation, has necessarily the effect of increasing the distinctness with which the parts are marked off from each other; and that so, out of the incoherent and indefinite, there arises the coherent and definite. But a coherent whole made up of definite parts definitely combined, must exhibit more definitely combined changes than a whole made up of parts that are neither definite in themselves nor in their combination. Hence, if living bodies display more than other bodies this structural definiteness, then, definiteness of combination must be a characteristic of the changes constituting Life; and must also distinguish the vital changes of higher organisms from those of lower organisms. Finally, however, we discovered that all these peculiarities are subordinate to the one fundamental peculiarity, that vital changes take place in correspondence with external co-existences and sequences; and that the highest possible Life is reached, when there is some inner relation of actions fitted to meet every outer relation of actions by which the organism can be affected. But this conception of the highest possible Life, is in perfect harmony with the conception, before arrived at, of the ultimate limit of Evolution. When treating of equilibration as exhibited in organic phenomena (*First Principles*, §§ 133, 134), it was pointed out, that the continual tendency is towards the establishment of a balance between inner and outer changes. It was shown that "the final structural arrangements must be such as will meet all the forces acting on the aggregate, by equivalent antagonistic forces," and that "the maintenance of such a moving equilibrium" as an organism displays, "requires the habitual genesis of internal forces corresponding in number, directions, and amounts, to the external incident forces—as many inner functions, single or combined, as there are single or combined outer actions to be met." It was shown, too, that the relations among conceptions and ideas, are ever in progress towards a better balance between mental actions and those actions in the environment to which conduct must be adjusted. So that that maintenance of a correspondence between inner and outer relations, which we have here found to constitute Life, and the

CHAPTER VII.

THE SCOPE OF BIOLOGY.

§ 37. We are now in a position to map-out the boundaries and divisions of our subject. Grouping together the general results arrived at in the first three chapters, and joining with them the results which the last three chapters have brought us to, we shall be prepared to comprehend the science of Biology as a whole; and to see how its truths may best be classified.

In the chapters treating of Organic Matter, the Actions of Forces on it, and its Reactions on Forces, the generalizations reached were these:—that organic matter is specially sensitive to surrounding agencies; that in consequence of the extreme instability of the compounds it contains, minute disturbances can cause in it large amounts of re-distribution; and that during the fall of its unstably-arranged atoms into stable arrangements, there are given out proportionately large amounts of motion. We saw that organic matter is so constituted, that small incident actions are capable of initiating great reactions—setting up extensive structural modifications, and liberating large quantities of power. In the chapters just concluded, the changes of which Life is made up, were shown to be so adjusted as to balance outer changes. And the general process of the adjustment we found resolves itself into this; that if in the environment there are any related actions, A and B, by which the organism is affected, then if A produces in the organism some change *a*, there follows in the organism some change *b*, fitted in time, direction, and amount to meet the action B—a change which is often required to be much larger than its antecedent. Mark, now, the relation between these two final results. On the one hand, for the maintenance of that correspondence between inner and outer actions which constitutes Life, an organism must be susceptible to small changes from small external forces (as in sensation), and must be able to initiate large changes in opposition to large external forces (as in muscular action). On the other hand, organic matter is at once extremely sensitive to disturbing agencies of all kinds, and is capable of suddenly evolving motion in great amounts. That is to say, the constitution of organic matter specially adapts it to receive and produce the internal changes required to balance external changes.

This being the general character of the vital Functions, and of the Matter in which they are performed, the science of Biology becomes an account of all the phenomena attendant on the performance of such Functions by such Matter—an account of all the conditions, concomitants, and consequences, under the various circumstances fallen into by living bodies. If all the functional phenomena which living bodies present, are, as we have concluded, incidents in the maintenance of a correspondence between inner and outer actions; and if all the structural phenomena which living bodies present, are direct or indirect concomitants of functional phenomena; then the entire Science of Life, must consist in a detailed interpretation of all these functional and structural phenomena in their relations to the phenomena of the environment. Immediately or mediately, proximately or remotely, every trait exhibited by organic bodies, as distinguished from inorganic bodies, must be referable to this continuous adjustment between their actions and the actions going on around them. Such being the extent and nature of our subject-matter, it may be thus divided.

1. An account of the structural phenomena presented by organisms. And this subdivides into:—

a. The structural phenomena presented by individual organisms.

b. The structural phenomena presented by successions of organisms.

2. An account of the functional phenomena which organisms present. And this, too, admits of sub-division into:—

a. The functional phenomena of individual organisms.

b. The functional phenomena of successions of organisms.

3. An account of the actions of Structure on Function, and the re-actions of Function on Structure. And like the others, this is divisible into:—

a. The actions and re-actions as exhibited in individual organisms.

b. The actions and re-actions as exhibited in successions of organisms.

4. An account of the phenomena attending the production of successions of organisms: in other words—the phenomena of Genesis.

There is, indeed, another mode of grouping the facts of Biology, with which all are familiar. According as they are facts of animal or vegetal life, they may be classed under the heads of Zoology and Botany. But this division, though convenient and indeed necessary for practical purposes, is one that does not here concern us. Dealing with organic structures and functions in connexion with their causes, conditions, concomitants, and consequences, Biology cannot divide itself into Animal-Biology and Vegetal-Biology; since the same fundamental classes of phenomena are common to both. Recognizing this familiar distinction only as much as convenience obliges us to do, let us now pass on to consider, more in detail, the classification of biologic phenomena, above set down in its leading outlines.

§ 38. The facts of structure which an individual or-

and types of organisms, there are hidden fundamental similarities; and that the courses of development in such groups and classes and types, though in many respects divergent, are in some essential respects, coincident. The wide truths thus disclosed, come under the heads of General Morphology and General Embryology.

By contrasting the structures of organisms, there is also achieved that grouping of the like and separation of the unlike, called Classification. First by observation of external characters; second by observation of internal characters; and third by observation of the phases of development; it is ascertained what organisms are most similar in all particulars; what organisms are like each other in every important attribute; what organisms have common primordial characters. Whence there finally results such an arrangement of organisms, that if certain structural attributes of any one be given, its other structural attributes may be *empirically* predicted; and which prepares the way for that interpretation of their relations and genesis, which forms an important part of *rational* Biology.

§ 39. The second main division of Biology, above described as embracing the functional phenomena of organisms, is that which is in part signified by Physiology: the remainder being what we distinguish as Psychology. Both of these fall into subdivisions that may best be treated separately. That part of Physiology which is concerned with the molecular changes going on in organisms, is known as Organic Chemistry. An account of the modes in which the force generated in organisms by chemical change, is transformed into other forces, and made to work the various organs that carry on the functions of Life, comes under the head of Organic Physics. Psychology, which is mainly concerned with the adjustment of vital actions to actions in the environment (in contrast with Physiology, which is mainly concerned with vital actions apart from actions in the environment) consists of two quite distinct portions. Objective Psychology deals with those functions of the nervo-muscular apparatus by which such organisms as possess it, are enabled to adjust inner to outer relations; and includes also, the study of the same functions as externally manifested in conduct. Subjective Psychology deals with the sensations, perceptions, ideas, emotions, and volitions that are the direct or indirect concomitants of this visible adjustment of inner to outer relations—considers these several kinds of consciousness in their genesis, and their connexions of co-existence and succession. Consciousness under its different modes and forms, being a subject-matter radically distinct in nature from the subject-matter of Biology in general; and the method of self-analysis, by which alone the laws of dependence among changes of consciousness can be found, being a method unparalleled by anything in the rest of Biology; we are obliged to regard Subjective Psychology as a separate study —not absolutely, of course, but relatively to the mind of each student. And since it would be very inconvenient to dissociate Objective Psychology from Subjective Psychology, we are practically compelled to deal with the two as forming an independent sub-science, to be treated apart from the lower divisions of Biology.

Obviously, the functional phenomena presented in successions of organisms, similarly divide into physiological and psychological. Under the physiological, come the modifications of bodily actions that arise in the course of generations, as concomitants of structural modifications; and these may be modifications, qualitative or quantitative, in the molecular changes classed as chemical, or in the organic actions classed as physical, or in both. Under the psychological, come the qualitative and quantitative modifications of instincts, feelings, conceptions, and mental changes in general, that occur in creatures having more or less intelligence, when certain of their conditions are changed. This, like the preceding department of Psychology, has in the abstract two different aspects—the objective and the subjective. Practically, however, the objective, which deals with these mental modifications as exhibited in the changing habits and abilities of successive generations of creatures, is the only one that admits of scientific investigation; since the corresponding alterations in consciousness, cannot be immediately known to any but the subjects of them. Evidently, convenience requires us to class this part of Psychology along with the other parts, in a distinct sub-science.

Light is thrown on functions, as well as on structures, by comparing organisms of different kinds. Comparative Physiology and Comparative Psychology, are the names given to those collections of facts respecting the homologies and analogies, bodily and mental, that are brought to light by this kind of inquiry. These classified observations concerning likenesses and differences of functions, are helpers to interpret functions in their essential natures and relations. Hence Comparative Physiology and Comparative Psychology are names of methods, rather than names of true subdivisions of Biology.

Here, however, as before, the comparison of special truths, besides facilitating their interpretation, brings to light certain general truths. Contrasting bodily and mental functions as exhibited in various orders of organisms, shows that there exists, more or less extensively, a community of processes and methods. Hence result two groups of abstract propositions, constituting General Physiology and General Psychology.

§ 40. In these various divisions and sub-divisions of the first two great departments of Biology, the phenomena of Structure are considered separately from the phenomena of Function, so far as separate treatment of them is possible. The third great department of Biology deals with them in their necessary connexions. It comprehends the determin-

tated, works, by re-action, altered structure; and how in succeeding generations, this altered structure may be made continually more marked by this altered function. Though logically distinct, these two sub-divisions of biologic inquiry cannot in practice be carried on apart. A speciality of structure which leads to an excess of function in any direction, is, by the perpetual re-action of function, rendered ever more decided. A speciality of function, by calling forth a corresponding speciality of structure, produces an increasingly efficient discharge of such function. Whichever of the two initiates the change, there goes on between them an unceasing action and re-action, producing in them co-ordinate modifications.

§ 41. The fourth great division of Biology, comprehending the phenomena of Genesis, may be conveniently separated into three sub-divisions.

Under the first, comes a description of all the special modes whereby the multiplication of organisms is carried on: which modes range themselves under the two chief heads of sexual and asexual. An account of Sexual Multiplication includes the various methods by which germs and ova are fertilized, and by which, after fertilization, they are furnished with the materials, and maintained in the conditions, needful for their development. An account of Asexual Multiplication includes the various methods by which, from the same fertilised germ or ovum, there are produced many organisms that are partially or totally independent of each other.

The second of these sub-divisions deals with the phenomena of Genesis in the abstract. It takes for its subject-matter, such general questions as—What is the end subserved by the union of sperm-cell and germ-cell? Why cannot all multiplication be carried on after the asexual method? What are the laws of hereditary transmission? What are the causes of variation?

The third sub-division is devoted to still more abstract aspects of the phenomena. Recognizing the general facts of multiplication, without reference to their modes or immediate causes, it concerns itself simply with the different rates of multiplication in different kinds of organisms, and different individuals of the same kind. Generalizing the numerous contrasts and variations of fertility, it seeks a rationale of them in their relations to other organic phenomena.

§ 42. Such appears to be the natural arrangement of divisions and sub-divisions which Biology presents, when regarded from the highest point of view, as the Science of Life—the science which has for its subject-matter, the correspondence of organic relations, with the relations amid which organisms exist. This, however, is a classification of the parts of Biology when fully developed; rather than a classification of the parts of Biology as it now stands. Several of the sub-divisions above named have no recognized existence; and sundry of the others are in quite rudimentary states. It is therefore impossible now to fill in, even in the roughest way, more than a part of the outlines here sketched.

Our course of inquiry being thus in great measure determined by the present state of knowledge, we are compelled to follow an order widely different from this ideal one. It will be necessary first to give an account of those empirical generalizations which naturalists and physiologists have established: arranging them rather with a view to facility of comprehension than to logical sequence; and appending to those which admit of it, such deductive interpretations as *First Principles* furnish us with. Having done this, we shall be the better prepared for dealing with the leading truths of Biology, in connexion with the doctrine of Evolution.

CHAPTER I.

GROWTH.

§ 43. PERHAPS the widest and most familiar induction of Biology, is that organisms grow. While, however, this is a characteristic so habitually and markedly displayed by plants and animals, as to be carelessly thought peculiar to them, it is really not so. Under appropriate conditions, increase of size takes place in inorganic aggregates, as well as in organic aggregates. Crystals grow; and often far more rapidly than living bodies. Where the requisite materials are supplied in the requisite forms, growth may be witnessed in non-crystalline masses: instance the fungus-like accumulation of carbon that takes place on the wick of an unsnuffed candle. On an immensely larger scale, we have growth in geologic formations: the slow accumulation of deposited sediment into a stratum, is not distinguishable from growth in its widest acceptation. And if we go back to the genesis of celestial bodies, assuming them to have arisen by Evolution, these, too, must have gradually passed into their concrete shapes through processes of growth. Growth is indeed a concomitant of Evolution; and if Evolution of one kind or other is universal, growth is universal—universal, that is, in the sense that all aggregates display it in some way at some period.

The essential community of nature between organic growth and inorganic growth, is, however, most clearly seen on observing that they both result in the same way. The segregation of different kinds of detritus from each other, as well as from the water carrying them, and their aggregation into distinct strata, is but an instance of a universal tendency towards the union of like units and the parting of unlike units (*First Principles*, § 123). The deposit of a crystal from a solution, is a differentiation of the previously mixed atoms; and an integration of one class of atoms into a solid body, and the other class into a liquid solvent. Is not the growth of an organism a substantially similar process? Around a plant there exist certain elements that are like the elements which form its substance; and its increase of size is effected by continually integrating these surrounding like elements with itself. Nor does the animal fundamentally differ in this respect from the plant or the crystal. Its food is a portion of the environing matter, that contains some compound atoms like some of the compound atoms constituting its tissues; and either through simple imbibition or through digestion, the animal eventually integrates with itself, units like those of which it is built up, and leaves behind the unlike units. To prevent misconception, it may be well to point out that growth, as here defined, must be distinguished from certain apparent and real augmentations of bulk which simulate it. Thus, the long, white potato-shoots thrown out in the dark, are produced at the expense of the substances which the tuber contains: they illustrate not the accumulation of organic matter, but simply its re-arrangement. Certain animal-embryos, again, during their early stages, increase considerably in size without assimilating any solids from the environment; and they do this by absorbing the surrounding water. Even in the highest organisms, as in children, there appears sometimes to occur a rapid gain in dimensions, that does not truly measure the added quantity of organic matter; but is in part due to changes analogous to those just named. Alterations of this

sition, we still find the limit of growth to have a great range. The smallest branched flowering plant is extremely insignificant by the side of a forest tree; and there is an enormous difference in bulk between the least and the greatest mammal. But on comparing members of the same species, we discover the limit of growth to be much less variable. Among the *Protozoa* and *Protophyta*, each kind has a tolerably constant adult size; and among the most complex organisms, the differences between those of the same kind that have reached maturity, are usually not very great. The compound plants do, indeed, sometimes present marked contrasts between stunted and well-grown individuals; but the higher animals diverge but inconsiderably from the average standards of their species.

On surveying the facts with a view of empirically generalising the causes of these differences, we are soon made aware that by variously combining and conflicting with each other, these causes produce great irregularities of result. It becomes manifest that no one of them can be traced to its consequences, unqualified by the rest. Hence the several statements contained in the following paragraphs, must be taken as subject to mutual modification.

Let us consider first, the connexion between degree of growth and complexity of structure. This connexion being involved with many others, becomes apparent only on so averaging the comparisons, as to eliminate differences among the rest. Nor does it hold at all where the conditions are radically dissimilar; as between plants and animals. But bearing in mind these qualifications, we shall see that organization has a determining influence on increase of mass. Of plants the lowest, classed as Thallogens, usually attain no considerable size. Lichens, Algæ, and Fungi, count among their numbers but few bulky species: the largest, such as certain Algæ found in antartic seas, not serving greatly to raise the average. Though among Acrogens there are some, as the Tree-ferns, which attain a considerable height, the majority are but of humble growth. The Endogens, including at one extreme small grasses and at the other tall palms, show us an average and a maximum greater than that reached by the Acrogens. And the Endogens are exceeded by the Exogens; among which are found the monarchs of the vegetal kingdom. Passing to animals, we meet the fact that the size attained by *Vertebrata* is usually much greater than the size attained by *Invertebrata*. Of invertebrate animals the smallest, classed as *Protozoa*, are also the simplest; and the largest, belonging to the *Annulosa* and *Mollusca*, are among the most complex of their respective types. Of vertebrate animals we see that the greatest are Mammals; and that though, in past epochs, there were reptiles of vast bulk, their bulk did not equal that of the whale. Between reptiles and birds, and between land-vertebrates and aquatic vertebrates, the relation does not hold: the conditions of existence being in these cases widely different. But among fishes as a class, and among reptiles as a class, it is observable that, speaking generally, the larger species are framed on the higher types. The critical reader, who has mentally checked these statements in passing them, has doubtless already seen that this relation is not a dependence of organization on growth, but a dependence of growth on organization. The majority of Exogens are smaller than some Endogens; many Endogens are exceeded in size by certain Acrogens; and even among Thallogens, the least developed of plants, there are kinds of a size which many plants of the highest order do not reach. Similarly among animals: there are plenty of Crustaceans less than *Actiniæ*; numerous reptiles are smaller than some fish; the majority of mammals are inferior in bulk to the largest reptiles; and in the contrast between a mouse and a well-grown *Medusa*, we see a creature that is elevated in the scale of organization, exceeded in mass by one that is extremely degraded. Clearly then, it cannot be held that high organization is habitually accompanied by great size. The proposition here illustrated is the converse one, that great size is habitually accompanied by high organisation. The conspicuous fact that the largest species of both animals and vegetals belong to the highest classes; and that throughout their various sub-classes the higher usually contain the more bulky forms; shows this connexion as clearly as we can expect it to be shown, amid so many modifying causes and conditions.

The relation between growth and supply of available nutriment, is too familiar a relation to need proving. There are, however, some aspects of it that must be contemplated before its implications can be fully appreciated. Among plants, which are all constantly in contact with the gaseous, liquid, and solid matters to be incorporated with their tissues; and which, in the same locality, receive not very unlike amounts of light and heat; differences in the supplies of available nutriment, have but a subordinate connexion with differences of growth. Though in a cluster of herbs springing up from the seeds let fall by a parent, the greater size of some than of others is doubtless due to better nutrition, consequent on accidental advantages; yet no such interpretation can be given of the contrast in size between these herbs and an adjacent tree. Other conditions here come into play: one of the most important probably being, an absence in the one case, and presence in the other, of an ability to secrete such a quantity of ligneous fibre as will produce a stem capable of supporting a large growth. Among animals, however, which (excepting some *Entozoa*) differ from plants in this, that instead of bathing their surfaces, the matters they subsist on are dispersed, and have to be obtained; the relation between available food and growth, is shown with more regularity. The *Protozoa*, living on microscopic fragments of organic matter contained in the surrounding water, are unable, during their brief lives, to accumulate any considerable quantity of nutriment. Polypes and *Molluscoida*, having for food these scarcely visible mem-

the animal kingdom, some case where classes otherwise allied, are contrasted in their locomotive activities. Let us compare birds on the one hand, with reptiles and mammals on the other. It is an accepted doctrine that birds are organized on a type closely allied to the reptilian type, but superior to it; and though in many respects the organization of birds is inferior to that of mammals, yet in other respects, as in the greater heterogeneity and integration of the skeleton, the more complex development of the respiratory system, and the higher temperature of the blood, it may be held that birds stand above mammals. Hence were growth dependent only on organization, we might infer that the limit of growth among birds should not be much short of that among mammals; and that the bird-type should admit of a larger growth than the reptile-type. Again, we see no manifest disadvantages under which birds labour in obtaining food, but from which reptiles and mammals are free. On the contrary, birds are able to get at food that is fixed beyond the reach of reptiles and mammals; and can catch food that is too swift of movement to be ordinarily caught by reptiles and mammals. Nevertheless, the limit of growth in birds, falls far below that reached by reptiles and mammals. With what other contrast between these classes, is this contrast connected? May we not suspect that it is connected with the contrast between their amounts of locomotive exertion? Whereas mammals (excepting bats, which are small), are during all their movements supported by solid surfaces or dense liquids; and whereas reptiles (excepting the ancient pterodactyles, which were not very large), are similarly restricted in their spheres of movement; the majority of birds move more or less habitually through a rare medium, in which they cannot support themselves without relatively great efforts. The conclusion that there exists this inverse ratio between growth and expenditure of force, is enforced by the significant fact, that those members of the class *Aves*, as the *Dinornis* and *Epiornis*, which approached in size to the larger *Mammalia* and *Reptilia*, were creatures incapable of flight—creatures which did not expend this excess of force in locomotion. Further evidence that there is an antagonism between the increase of bulk and the quantity of motion evolved by an organism, is supplied by the general experience, that human beings and domestic animals, when overworked while growing, are prevented from attaining the ordinary dimensions.

One other general truth concerning degrees of growth, must be set down. It is a rule, having exceptions of no great importance, that large organisms commence their separate existences as masses of organic matter more or less considerable in size, and commonly with organizations more or less advanced; and that throughout each organic sub-kingdom, there is a certain general, though irregular, relation between the initial and the final bulks. Vegetals exhibit this relation much less clearly and constantly than animals. Yet though, among the plants that begin life as minute spores, there are some which, under their special conditions, grow to considerable sizes, the immense majority of them remain small. While, conversely, the great Endogens and Exogens, when thrown off from their parents, have already the formed organs of young plants, to which are attached large stores of highly nutritive matter. That is to say, where the young plant consists merely of a centre of development, the ultimate growth is commonly insignificant; but where the growth is to become great, there exists to start with, a well-developed embryo and a stock of assimilable matter. Throughout the animal kingdom, this relation is tolerably regular. Save among classes that escape the ordinary requirements of animal life, small germs or eggs do not give rise to bulky creatures. Where great bulk is to be reached, the young proceeds from an egg of considerable bulk, or is born of considerable bulk ready-organized and partially active. In the class fishes, for instance, a certain average proportion obtains between the sizes of the ova and the sizes of the adult indidividuals; and among the highest fishes, as sharks, the eggs are comparatively few and comparatively large. Reptiles have eggs that are smaller in number, and relatively greater in mass, than those of fishes; and throughout this class, too, there is a general ratio between the bulk of the egg and the bulk of the adult creature. As a group, birds show us a further limitation in the number of their eggs, and a further increase in their relative sizes; and from the minute eggs of the humming-bird up to the immense ones of the *Epiornis*, holding several quarts, we see that, speaking generally, the greater the eggs, the greater the birds. Finally, among mammals (omitting the marsupials) the young are born, not only of comparatively large sizes, but with advanced organizations; and throughout this sub-division of the vertebrata, as throughout the others, there is a manifest connexion between the sizes at birth and the sizes at maturity. As having a kindred meaning, there must finally be noted the fact, that the young of these highest animals, besides starting in life with bodies of considerable sizes, almost fully organized, are, during subsequent periods of greater or less length, supplied with nutriment—in birds by feeding, and in mammals by suckling and afterwards by feeding. That is to say, beyond the mass and organization directly bequeathed, a bird or mammal obtains a further large mass at but little cost to itself.

Were an exhaustive treatment of the topic intended, it would be needful to give a paragraph to each of the many incidental circumstances by which growth may be aided or restricted. Such facts as that an entozoon is limited by the size of the creature, or even the organ, in which it thrives; that an epizoon, though getting abundant nutriment without appreciable exertion, is restricted to that small bulk at which it escapes ready detection by the animal it infests; that sometimes, as in the weasel, smallness is a condition to successful pursuit of the animals preyed upon; and that at other times, the advantage of resembling certain other crea-

exceptions, are, by the conditions of their existence, required to take in nutriment through one specialized part of the body, it is clear that there must be a means whereby other parts of the body, to be supported by this nutriment, must have it conveyed to them. It is clear that for an equally efficient maintenance of their nutrition, the parts of a large mass must have a more elaborate propelling and conducting apparatus; and that in proportion as these parts undergo greater waste, a yet higher development of the vascular system is necessitated. Similarly with the pre-requisites to those mechanical motions which animals are required to perform. The parts of a mass cannot be made to move, and have their movements so co-ordinated as to produce locomotive and other actions, without certain structural arrangements; and, other things equal, a given amount of such activity requires more involved structural arrangements in a large mass than in a small one. There must at least be a co-ordinating apparatus presenting greater contrasts in its central and peripheral parts.

The qualified dependence of growth on organization, is equally implied when we study it in connexion with that adjustment of inner to outer relations which constitutes Life. In plants this is not conspicuous, because the adjustment of inner to outer relations is but small. Still, it is visible in the fact that the condition on which only a plant can grow to a great size, is, that it shall, by the development of a massive trunk, present inner relations of forces fitted to counterbalance those outer relations of forces, which tend continually and occasionally to overthrow it; and this formation of a core of regularly-arranged woody fibres, is an advance in organization. Throughout the animal kingdom, this connexion of phenomena is manifest. To obtain materials for growth; to avoid injuries, which interfere with growth; and to escape those enemies which bring growth to a sudden end; implies in the organism, the means of fitting its movements to meet numerous external co-existences and sequences—

implies such various structural arrangements as shall make possible these variously-adapted actions. It cannot be questioned that, everything else remaining constant, a more complex animal, capable of adjusting its conduct to a greater number of surrounding contingences, will be the better able to secure food and evade damage, and so to increase bulk. And evidently, without any qualification, we may say that a large animal, living under such complex conditions of existence as everywhere obtain, is not possible without comparatively high organization.

While, then, this relation is traversed and obscured by sundry other relations, it cannot but exist. Deductively we see that it must be modified, as inductively we saw that it is modified, by the circumstances amid which each kind of organism is placed; but that it is always a factor in determining the result.

§ 45. That growth is, *cæteris paribus*, dependent on the supply of assimilable matter, is a proposition so continually illustrated by special experience, as well as so obvious from general experience, that it would scarcely need stating, were it not requisite to notice the qualifications with which it must be taken. The materials which each organism requires for building itself up, are not of one kind, but of several kinds. As a vehicle for transferring matter through their structures, all organisms require water as well as solid constituents; and however abundant the solid constituents, there can be no growth in the absence of water. Among the solids supplied, there must be a proportion ranging within certain limits. A plant round which carbonic acid, water, and ammonia exist in the right quantities, may yet be arrested in its growth by a deficiency of silica. The total absence of lime from its food, may stop the formation of a mammal's skeleton: thus dwarfing, if not eventually destroying, the mammal; and this, no matter what quantities of other needful colloids and crystalloids are furnished.

Again, the truth that, other things equal, growth varies according to the supply of nutriment, has to be qualified by the condition, that the supply shall not exceed the ability to appropriate it. In the vegetal kingdom, the assimilating surface being external, and admitting of rapid expansion by the formation of new roots, shoots, and leaves, the effect of this limitation is not conspicuous: by artificially supplying plants with those materials which they have usually the most difficulty in obtaining, we can greatly facilitate their growth; and so can produce striking differences of size in the same species. Even here, however, the effect is confined within the limits of the ability to appropriate; since in the absence of that solar light and heat, by the help of which the chief appropriation is carried on, the additional materials of growth are useless. In the animal kingdom this restriction is rigorous. The absorbent surface being, in the great majority of cases, internal; having a comparatively small area, which cannot be greatly enlarged without re-construction of the whole body; and being in connexion with a vascular system, which must also be re-constructed before any considerable increase of nutriment can be made available; it is clear that beyond a certain point, very soon reached, increase of nutriment will not cause increase of growth. On the contrary, if the quantity of nutriment taken in, is greatly beyond the absorbent power, the excess, becoming an obstacle to the regular working of the organism, may retard growth rather than advance it.

While then it is certain, *à priori*, that there cannot be growth in the absence of such substances as those of which an organism consists; and while it is equally certain that the amount of growth must primarily be governed by the supply of these substances; it is not less certain that extra supply will not produce extra growth, beyond a point very soon reached. Deduction shows to be necessary, as induction makes familiar, the truths that, the value of food for purposes of growth depends not on the quantity of the various

of nutritive matter which the pre-existing structure of an organism enables it to absorb; and it is a necessary corollary from the persistence of force, that the matter accumulated as growth, cannot exceed that surplus which remains undecomposed, after the production of the required amounts of sensible and insensible motion. This, which would be rigorously true under all conditions, if exactly the same substances were used in exactly the same proportions, for the production of force and for the formation of tissue, requires, however, to be taken with the qualification, that some of the force-evolving substances are not constituents of tissue; and that thus, there may be a genesis of force which is not at the expense of potential growth. But since organisms (or at least animal organisms, with which we are here chiefly concerned,) have a certain power of selective absorption, which, partially in an individual and more completely in a race, adapts the proportions of the substances absorbed to the needs of the system; then if a certain habitual expenditure of force, leads to a certain habitual absorption of force-evolving matters that are not available for growth; and if, were there less need for such matters, the ability to absorb matters available for growth would be increased to an equivalent extent; it follows that the antagonism described, does, in the long run, hold even without this qualification. Hence, growth is substantially equivalent to the absorbed nutriment, minus the nutriment used up in action.

This, however, is no answer to the question—why has individual growth a limit? The antagonism described, does not manifestly account for the fact, that in every domestic animal the increments of growth bear continually decreasing ratios to the mass, and finally come to an end. Nevertheless, it is demonstrable that the excess of absorbed over expended nutriment, must, other things equal, become less as the size of the animal becomes greater. In similarly-shaped bodies, the masses vary as the cubes of the dimensions; whereas the strengths vary as the squares of the dimensions. See here the solution of the problem. Supposing a creature which a year ago was one foot high, has now become two feet high, while it is unchanged in proportions and structure; what are the necessary concomitant changes that have taken place in it? It is eight times as heavy; that is to say, it has to resist eight times the strain which gravitation puts on its structure; and in producing, as well as in arresting, every one of its movements, it has to overcome eight times the inertia. Meanwhile, the muscles and bones have severally increased their contractile and resisting powers in proportion to the areas of their transverse sections; and hence are severally but four times as strong as they were. Thus, while the creature has doubled in height, and while its ability to overcome forces has quadrupled, the forces it has to overcome have grown eight times as great. Hence, to raise its body through a given space, its muscles have to be contracted with twice the intensity, at a double cost of matter expended. This necessity will be seen still more clearly if we leave out the motor apparatus, and consider only the forces required and the means of supplying them. For since, in similar bodies, the areas vary as the squares of the dimensions, and the masses vary as the cubes; it follows that the absorbing surface has become four times as great, while the weight to be moved by the matter absorbed has become eight times as great. If then, a year ago, the absorbing surface could take up twice as much nutriment as was needed for expenditure, thus leaving one-half for growth, it is now able only just to meet expenditure, and can provide nothing for growth. However great the excess of assimilation over waste, may be during the early life of an active organism, we see that because a series of numbers increasing as the cubes, overtakes a series increasing as the squares, even though starting from a much smaller number, there must be reached, if the organism lives long enough, a point at which the surplus assimilation is brought down to nothing—a point at which expenditure balances nutrition—a state of moving equilibrium. This, however, though the chief, is not the sole, varying relation between degrees of growth and amounts of expended force. There are two more; one of which conspires with the last, while the other conflicts with it. Consider in the first place, the cost at which nutriment is distributed through the body, and effete matters removed from it. Each increment of growth being added at the periphery of the organism, the force expended in the transfer of matter must increase in a rapid progression—a progression more rapid than that of the mass. But as the dynamic expense of distribution is small compared with the dynamic value of the materials distributed, this item in the calculation is unimportant. Now consider, in the second place, the changing proportion between production and loss of heat. In similar organisms, the quantities of heat generated by similar actions going on throughout their substance, must increase as the masses, or as the cubes of the dimensions. Meanwhile, the surfaces from which loss of heat by radiation takes place, increase only as the squares of the dimensions. Though the loss of heat does not therefore increase only as the squares of the dimensions, it certainly increases at a smaller rate than the cubes. And to the extent that augmentation of mass results in a greater retention of heat, it effects an economization of force. This advantage is not, however, so important as at first appears. Organic heat is a concomitant of organic action, and is so abundantly produced during action, that the loss of it is then of no consequence: indeed the loss is often not rapid enough to keep the supply from rising to an inconvenient excess. It is only in respect of that maintenance of heat which is needful during quiescence, that large organisms have an advantage over small ones in this relatively diminished loss. Thus these two subsidiary relations between degrees of growth and amounts of expended force, being in antagonism with each other, we may conclude that their differential result does not greatly modify the result of the chief relation previously set forth.

Any one who proceeds to test this deduction, will find some

is said to grow as long as it lives; and there appears reason to think that some predaceous fishes, such as the pike, do the same. That these animals of comparatively high organisation, have no definite limits of growth, is, however, an exceptional fact due to the exceptional non-fulfilment of those conditions which entail limitation. What kind of life does a crocodile lead? It is a cold-blooded, or almost cold-blooded, creature; that is, it expends very little for the maintenance of heat. It is habitually inert: not chasing prey, but lying in wait for it; and undergoes considerable exertion only during its occasional brief contests with prey. Such other exertion as is, at intervals, needful for moving from place to place, is rendered small by the small difference between the animal's specific gravity and that of water. Thus the crocodile expends in muscular action, an amount of force that is insignificant compared with the force commonly expended by land-animals. Hence its habitual assimilation is diminished much less than usual by habitual waste; and beginning with an excessive disproportion between the two, it is quite possible for the one never quite to lose its advance over the other while life continues. On looking closer into such cases as this and that of the pike, which is similarly cold-blooded, similarly lies in wait, and is similarly able to obtain larger and larger kinds of prey as it increases in size; we discover a further reason for this absence of a definite limit. The mechanical causes necessitating a limit, are here only partially in action. For a creature living in a medium of nearly the same density as its body, has not constantly to overcome that gravitative force which is the chief resistance to be met by terrestrial animals: it has not to expend for this purpose, a muscular power that is large at the outset, and increases as the cubes of its dimensions. The only force increasing as the cubes of its dimensions, which it has thus to overcome, is the inertia of its parts. The exceptional continuance of growth observed in creatures so circumstanced, is therefore perfectly explicable.

§ 47. Obviously this antagonism between accumulation and expenditure, must be a leading cause of the contrasts in size between allied organisms that are in many respects similarly conditioned. The life followed by each kind of animal, is one involving a certain average amount of exertion for the obtainment of a given amount of nutriment—an exertion, part of which goes to the gathering or catching of food, part to the tearing and mastication of it, and part to the after-processes requisite for separating the nutritive atoms—an exertion which therefore varies according as the food is abundant or scarce, fixed or moving, according as it is mechanically easy or difficult to deal with when secured, and according as it is, or is not, readily soluble. Hence, while among animals of the same species having the same mode of life, there will be a tolerably constant ratio between accumulation and expenditure, and therefore a tolerably constant limit of growth; there is every reason to expect that different species, following different modes of life, will have unlike ratios between accumulation and expenditure, and therefore unlike limits of growth.

Though the facts as inductively established, show a general harmony with this deduction, we cannot usually trace this harmony in any specific way; since the conflicting and conspiring causes which affect growth are so numerous. The only contrast which seems fairly to the point, is the before-named one between the vertebrates which fly, and the most nearly-allied vertebrates which do not fly: the differences in degrees of organization and relations to food, being not such as seriously to affect the comparison. If it be admitted that birds habitually expend more force than mammals and reptiles, then it will follow *à priori*, that, other things being tolerably equal, they should have a lower limit of growth than mammals and reptiles; and this we know to be the fact *à posteriori*.

§ 48. One of the chief causes, if not the chief cause, of the differences between the sizes of organisms, has yet to be considered. We are introduced to it by pushing the above inquiry a little further. Small animals have been shown to possess an advantage over large ones, in the greater ratio which, other things equal, assimilation bears to expenditure: and we have seen that hence, small animals in becoming large ones, gradually lose that surplus of assimilative power which they had, and eventually cannot assimilate more than is required to balance waste. But how come these animals while young and small, to have surplus assimilative powers? Have all animals equal surplus of assimilative powers? And if not, how far do differences between the surpluses determine differences between the limits of growth? We shall find in the answers to these questions, the interpretation of many marked contrasts in growth that are not due to any of the causes above assigned. For example, an ox immensely exceeds a sheep in mass. Yet the two live from generation to generation in the same fields, eat the same grass and turnips, obtain these aliments with the same small expenditure of force, and differ scarcely at all in their degrees of organization. Whence arises, then, their striking unlikeness of bulk?

We noted when studying the phenomena of growth inductively, that organisms of the larger and higher types, commence their separate existences, as masses of organic matter having tolerable magnitudes. Speaking generally, we saw that throughout each organic sub-kingdom, the acquirement of great bulk occurs only where the incipient bulk and organization are considerable; and that they are the more considerable in proportion to the complexity of the life which the organism is to lead.

The deductive interpretation of this induction may best be commenced by an analogy. A street orange-vendor makes but a trifling profit on each transaction; and unless more than ordinarily fortunate, he is unable to realize during the day a larger amount than will meet his wants: leaving him to start on the morrow in the same condition as

And clearly, the ability of an organism to expend largely and assimilate largely, so as to make a large surplus, presupposes a large physiological capital, in the shape of organic matter more or less complete in its structural arrangements.

Throughout the vegetal kingdom, the illustrations of this truth are not conspicuous and regular: the obvious reason being, that since plants are accumulators and in so small a degree expenders, the premises of the above argument are but very partially fulfilled. The food of plants (excepting Fungi and certain parasites) being in a great measure the same for all, and bathing all so that it can be absorbed without effort, their vital processes result almost entirely in profit. Once fairly rooted in a fit place, a plant may thus from the outset add its entire returns to capital; and may soon be able to carry on its processes on a large scale, though it does not at first do so. When, however, plants are expenders, namely, during their germination and first stages of growth, their degrees of growth *are* determined by their amounts of vital capital. It is because the young tree commences life with a ready-formed embryo and store of food sufficient to last for some time, that it is enabled to strike root and lift its head above the surrounding herbage. Throughout the animal kingdom, however, the necessity of this relation is everywhere obvious. The small carnivore preying on small herbivores, can increase in size only by small increments: its organization unfitting it to digest larger creatures, even if it can kill them, it cannot profit by amounts of nutriment exceeding a narrow limit; and its possible increments of growth being small to set out with, and rapidly decreasing, must come to an end before any considerable size is attained. Manifestly the young lion, born of tolerable bulk, suckled until much bigger, and fed until half-grown, is enabled by the power and organization which he thus gets gratis, to catch and kill animals of size enough to give him the large supply of nutriment needed to meet his large expenditure, and yet leave a large surplus for growth. Thus then is explained the above-named contrast between the ox and the sheep. A calf and a lamb commence their physiological transactions on widely different scales; their first increments of growth are similarly contrasted in their amounts; and the two diminishing series of such increments, end at similarly-contrasted limits.

§ 49. Such are the several conditions by which the phenomena of growth are governed. Conspiring and conflicting in endless different ways and degrees, they in every case qualify more or less differently each other's effects. Hence it happens that we are obliged to state each generalization as true on the average, or to make the proviso—other things equal.

Understood, in this qualified form, our conclusions are these. First, that growth being an integration with the organism, of such environing matters as are of like nature with the matters composing the organism, its growth is dependent on the available supply of such matters: this is alike a truth established by experience, and an inference from the truth given in our forms of thought (*First Principles*, § 67). Second, that the available supply of assimilable matter being the same, and other conditions not dissimilar, the degree of growth varies according to the surplus of nutrition over expenditure—a generalization which is illustrated in some of the broader contrasts between different divisions of organisms, and is a direct corollary from the persistence of force. Third, that in the same organism, the surplus of nutrition over expenditure is a variable quantity; and that growth is unlimited or has a definite limit, according as the surplus does or does not progressively decrease. This proposition we found on the one hand exemplified by the unceasing growth of organisms that do not expend force; by the growth, slowly diminishing but never completely ceasing, of organisms that expend comparatively little force; and by the definitely limited growth of organisms that expend much force; and on the other hand, we found it to follow from a certain relative increase of expenditure that necessarily accompanies increase of bulk, and to be therefore an indirect corollary from the persistence of force. Fourth, that among organisms which are large expenders of force, the size ultimately attained is, other things equal, determined by the initial size: in proof of which conclusion we have abundant facts, as well as the *à priori* necessity that the sum-totals of analogous diminishing series, must depend upon the amounts of their initial terms. Fifth, that where the likeness of other circumstances permits a comparison, the possible extent of growth depends on the degree of organization: an inference testified to by the larger forms among the various divisions and sub-divisions of organisms; and inferable *à priori* from the conditions of existence.

minute structure. Let us glance at these propositions in the concrete. Leaving out those Rhizopods which are wholly structureless, every plant and animal in its earliest stage, consists of a spherical sac, full of liquid containing organic matter, in which is suspended a nucleated cell, more or less distinct from the rest; and the first changes that occur in the germ thus constituted, are changes that take place round centres produced by division of the original centre. From this type of structure, the simplest organisms do not depart; or depart in no definite or conspicuous ways. Among plants, the *Uredo* and the several tribes of *Protococci* permanently maintain such a central distribution; while among animals, it is permanently maintained by creatures like the *Gregarina*, and in a different manner by the *Amœba*, *Actinophrys*, and their allies. In larger organisms, made up chiefly of units that are analogous in structure to these simplest organisms, the formation of units ever continues to take place round points or nuclei; though the arrangement of these units into groups and wholes may proceed after another method.

Central development may be distinguished into *unicentral* and *multicentral*; according as the product of the original germ, develops symmetrically round one centre, or develops without subordination to one centre—develops, that is, in subordination to many centres. Unicentral development, as displayed not in the formation of single cells but in the formation of aggregates, is not common. The animal kingdom shows it only in the small group named *Thalassicollæ*: inert, spherical masses of jelly, with scarcely any organization, which are found floating in southern seas. It is feebly represented in the vegetal kingdom by the *Volvox globator*. On the other hand, multicentral development, or development round insubordinate centres, is variously exemplified in both divisions of the organic world. It is exemplified in two distinct ways, according as the insubordination among the centres of development is partial or total

We may most conveniently consider it under the heads hence arising.

Total insubordination among the centres of development, is shown where the units or cells, as fast as they are severally formed, part company and lead independent lives. This, in the vegetal kingdom, habitually occurs among the *Protophyta;* and in the animal kingdom, among the *Protozoa.* Partial insubordination is seen in those somewhat advanced organisms, that consist of units which, though they have not separated, have so little mutual dependence that the aggregate they form is irregular. Among plants, the Thallogens very generally exemplify this mode of development. Lichens, spreading with flat or corrugated edges in this or that direction, as the conditions determine, have no manifest co-ordination of parts. In the *Algæ*, the Nostocs similarly show us an unsymmetrical structure. Of *Fungi*, the sessile and creeping kinds display no further dependence of one part on another, than is implied by their cohesion. And even in such better-organized plants as the *Marchantia*, the general arrangement shows no reference to a directive centre. Among animals, many of the Sponges may be cited as being thus devoid of that co-ordination implied by symmetry: the Amæba-like units composing them, though they have some subordination to local centres, have no subordination to a general centre. To distinguish that kind of development in which the whole product of a germ coheres in one mass, from that kind of development in which it does not, Professor Huxley has introduced the words "*continuous*" and "*discontinuous;*" and these seem the best fitted for the purpose. Multicentral development, then, is divisible into continuous and discontinuous.

From central development we pass insensibly to that higher kind of development for which *axial* seems the most appropriate name. A tendency towards this is vaguely manifested almost everywhere. The great majority even of *Protophyta* and *Protozoa* have different longitudinal and transverse dimensions—have an obscure if not a distinct axial structure. The originally cellular units out of which higher organisms are mainly built up, usually pass into shapes that are subordinated to lines rather than to points. And in the higher organisms, considered as wholes, an arrangement of parts in relation to an axis is distinct and nearly universal. We see it in the superior orders of Thallogens; and in all the Acrogens, Endogens, and Exogens. With few exceptions the *Cœlenterata* clearly exhibit it; it is traceable, though less conspicuously, throughout the *Mollusca;* and the *Annulosa* and *Vertebrata* uniformly show it with perfect definiteness.

This kind of development, like the first kind, is of two orders. The whole germ-product may arrange itself round a single axis, or it may arrange itself round many axes; the structure may be *uniaxial* or *multiaxial.* Each division of the organic kingdom furnishes examples of both these orders. In such *Fungi* as exhibit axial development at all, we commonly see development round a single axis. Some of the *Algæ*, as the common tangle, show us this arrangement. And of the higher plants, many Endogens and small Exogens are uniaxial. Of animals, the advanced are without exception in this category. There is no known vertebrate in which the whole of the germ-product is not subordinated to a single axis. In the more fully-organized *Annulosa*, the like is almost universal; as it is also in the superior orders of *Mollusca.* Multiaxial development occurs in most of the plants we are familiar with—every branch of a shrub or tree being an independent axis. But while in the vegetal kingdom, multiaxial development prevails among the highest types; in the animal kingdom, it prevails only among the lowest types. It is extremely general, if not universal, among the *Cœlenterata;* it is characteristic of the *Molluscoida;* among Molluscs the compound Ascidians exhibit it; and it is seen, though under another form, in the inferior *Annulosa.*

Development that is axial, like development that is central,

Any one adequately acquainted with the facts, may readily raise objections to this arrangement. He may name forms which do not obviously come under any of these heads. He may point to plants that are for a time multicentral, but afterwards develop axially. And from lower types of animals, he may choose many in which the continuous and discontinuous modes are both displayed. But, as already hinted, an arrangement free from such anomalies must be impossible, if the various orders of organization have arisen by Evolution. The one above sketched out, is to be regarded as only a rough grouping of the facts, which helps us to a conception of them in their totality; and so regarded, it will be of service when we come to treat of Individuality and Reproduction.

§ 51. From these most general external aspects of organic development, let us now turn to its internal and more special aspects. When treating of Evolution as a universal process of things, a rude outline of the course of structural changes in organisms was given (*First Principles*, §§ 43, 55, 56). Here, however, it will be proper to describe these changes more fully.

The bud of any common plant in its earliest stage, consists of a small hemispherical or sub-conical projection. While it increases most rapidly at the apex, this presently develops on one side of its base, a smaller projection of like general shape with itself. Here is the rudiment of a leaf; which presently spreads more or less round the base of the central hemisphere or main axis. At the same time that the central hemisphere rises higher, this lateral prominence, also increasing, gives rise to subordinate prominences or lobes. These are the rudiments of stipules, where the leaves are stipulated. Meanwhile, towards the other side of the main axis, and somewhat higher up, another lateral prominence arising, marks the origin of a second leaf. By the time that the first leaf has produced another pair of lobes, and the second leaf has produced its primary pair, the central hemisphere, still increasing at its apex, exhibits the rudiment of a third leaf. Similarly throughout. While the germ of each succeeding leaf thus arises, the germs of the previous leaves, in the order of their priority, are changing their rude nodulated shapes into flattened-out expansions; which slowly put on those sharp outlines they show when unfolded. Thus from that extremely indefinite figure, a rounded lump, giving off from time to time lateral lumps, which severally becoming symmetrically lobed, gradually assume specific and involved forms, we pass little by little to that comparatively complex thing—a leaf-bearing shoot. Internally, a bud undergoes analogous changes. The layer of substance which forms the surface of the hemisphere, and in which these metamorphoses commence, consists of a transparent, irregularly-aggregated mass of cells and centres of growth, not formed into a tissue. Especially is this the case at the apex, where the vital activity is the greatest. Here the primitive cellular mass passes without any line of demarcation into the tissues that are developing from it. While, by continued cell-multiplication this layer increases, and doing so most rapidly at the apex thrusts outwards its lateral portions, these begin to exhibit differentiations. "Gradually," says Schleiden, "separate masses of cells, with a distinct and definite outline, appear in this chaos, and they cease to partake of the process of growth going on. At first the epidermis is separated, then the vascular bundles, later the parenchyma." Similarly with the lateral buds whence leaves arise. In the, at first, unorganized mass of cells constituting the rudimentary leaf, there are formed vascular bundles which eventually become the veins of the leaf; and gradually there appear also, though in ways that have not been specified, the parenchyma and the epithelium. Nor do we fail to find an essentially parallel set of changes, when we trace the histories of the individual cells. While the tissues they compose are separating, the cells are growing step by step more unlike. Some become flat, some polyhedral, some cylindrical, some prismatic, some spindle-shaped. These develop spiral fibres in their interiors; and those, net-works of fibres. Here a number of cells unite together to form a tube; and there they become solid by the internal deposition of woody or other matter. Through such changes, too numerous and involved to be here detailed, the originally uniform cells go on diverging and re-diverging, until there are produced various forms that seem to have very little in common.

The arm of a man makes its first appearance in as simple a way as does the shoot of a plant. According to Bischoff, it buds-out from the side of the embryo, as a little tongue-shaped projection, presenting no differences of parts; and it might serve for the rudiment of some one of the various other organs that also arise as buds. Continuing to lengthen, it presently becomes somewhat enlarged at its end; and is then described as a pedicle bearing a flattened, round-edged lump. This lump is the representative of the future hand; and the pedicle, of the future arm. By and by, at the edges of this flattened lump, there appear four clefts, dividing from each other the buds of the future fingers; and the hand as a whole grows a little more distinguishable from the arm. Up to this time, the pedicle has remained one continuous piece; but it now begins to show a bend at its centre, which indicates the division into arm and forearm. The distinctions thus rudely indicated, gradually increase: the fingers elongate and become jointed; and the proportions of all the parts, originally very unlike those of the complete limb, slowly approximate to them. During its bud-like stage, the rudimentary arm is nothing but a homogeneous mass of simple cells, without any arrangement. By the diverse changes they gradually undergo, these cells are transformed into bones, muscles, blood-vessels, and nerves. The extreme softness and delicacy of this primary cellular tissue, renders it difficult to trace the initial stages of these differentiations. In consequence of the colour of their contents, the blood-vessels are the first parts to become visible. Afterwards the cartilaginous parts, which are the bases of the future bones, become marked out by the

ology comes next in order. Von Baer found that in its earliest stage, every organism has the greatest number of characters in common with all other organisms in their earliest stages; that at a stage somewhat later, its structure is like the structures displayed at corresponding phases by a less extensive multitude of organisms; that at each subsequent stage, traits are acquired which successively distinguish the developing embryo from groups of embryos that it previously resembled—thus step by step diminishing the group of embryos which it still resembles; and that thus the class of similar forms, is finally narrowed to the species of which it is a member. This abstract proposition will perhaps not be fully realized by the general reader. It will be best to re-state it in a concrete shape. The germ out of which a human being is evolved, differs in no visible respect from the germ out of which every animal and plant is evolved. The first conspicuous structural change undergone by this human germ, is one characterizing the germs of animals only—differentiates them from the germs of plants. The next distinction established, is a distinction exhibited by all *Vertebrata;* but never exhibited by *Annulosa*, *Mollusca*, or *Cœlenterata*. Instead of continuing to resemble, as it now does, the rudiments of all fishes, reptiles, birds, and mammals; this rudiment of a man, assumes a structure that is seen only in the rudiments of mammals. Later, the embryo undergoes changes which exclude it from the group of implacental mammals; and prove that it belongs to the group of placental mammals. Later still, it grows unlike the embryos of those placental mammals distinguished as ungulate or hoofed; and continues to resemble only the unguiculate or clawed. By and by, it ceases to be like any fœtuses but those of the quadrumana; and eventually the fœtuses of only the higher quadrumana are simulated. Lastly, at birth, the infant, belonging to whichever human race it may do, is structurally very much like the infants of all other human races; and only afterwards acquires those various minor peculiarities of form that distinguish the variety of man to which it belongs.

The generalization here expressed and illustrated, must not be confounded with an erroneous semblance of it that has obtained considerable currency. An impression has been given by those who have popularized the statements of embryologists, that during its development, each higher organism passes through stages in which it resembles the adult forms of lower organisms—that the embryo of a man is at one time like a fish, and at another time like a reptile. This is not the fact. The fact established is, that up to a certain point, the embryos of a man and a fish continue similar, and that then differences begin to appear and increase—the one embryo approaching more and more towards the form of a fish; the other diverging from it more and more. And so with the resemblances to the more advanced types. Supposing the germs of all kinds of organisms to be simultaneously developing, we may say that all members of the vast multitude take their first steps in the same direction; that at the second step one-half of this vast multitude diverges from the other half, and thereafter follows a different course of development; that the immense assemblage contained in either of these divisions, very soon again shows a tendency to take two or more routes of development; that each of the two or more minor assemblages thus resulting, shows for a time but small divergences among its members, but presently again divides into groups which separate ever more widely as they progress; and so on, until each organism, when nearly complete, is accompanied in its further modifications only by organisms of the same species; and last of all, assumes the peculiarities which distinguish it as an individual—diverges to a slight extent to the organisms it is most like. The reader must also be cautioned against accepting this generalization as exact. The likenesses thus successively displayed are not precise but approximate. Only leading characteristics are the same: not all the details. It is as though in one of the diverging groups just described, each kind of organism, though having a general direction of development like that of the others it is for a time travelling with, shows from the first a tendency to leave the general route—a tendency which presently becomes strongly marked. Making all requisite qualifications, however, these resemblances remain conspicuous; and the fact that they follow each other in the way described, is a fact of great significance.

§ 53. This comparison between the course of development in any creature, and the course of development in all other creatures—this arrival at the conclusion that the course of development in each, at first the same as in all others, becomes stage by stage differentiated from the courses of all others, brings us within view of an allied conclusion. If we contemplate the successive stages passed through by any higher organism, and observe the relation between it and its environment at each of these stages; we shall see that this relation is modified in a way analogous to that in which the relation between the organism and its environment is modified, as we advance from the lowest to the highest grades. Along with the progressing differentiation of each organism from others, we find a progressing differentiation of it from its environment; like that progressing differentiation from the environment which we meet with in the ascending forms of life. Let us first glance at the way in which the ascending forms of life exhibit this progressing differentiation from the environment.

In the first place, it is illustrated in *structure*. Advance from the homogeneous to the heterogeneous, itself involves an increasing distinction from the inorganic world. In the lowest *Protozoa* we have a simplicity approaching to that of air, water, or earth; and the ascent to organisms of greater and greater complexity of structure, is an ascent to organisms that are in that respect more strongly contrasted with the structureless environment. In *form*, again,

creatures, superior specific gravity is a standard of general superiority, yet we may fairly say that the superior orders of them, when divested of the appliances by which their specific gravity is regulated, differ more from water in their relative weight than do the lowest. In terrestrial organisms, the contrast becomes extremely marked. Trees and plants, in common with insects, reptiles, mammals, birds, are all of a specific gravity considerably less than that of the earth and immensely greater than that of the air. Yet further, we see the law similarly fulfilled in respect of *temperature*. Plants generate but extremely small quantities of heat, which are to be detected only by very delicate experiments; and practically they may be considered as having the same temperature as their environment. The temperature of aquatic animals is very little above that of the surrounding water: that of the invertebrata being mostly less than a degree above it, and that of fishes not exceeding it by more than two or three degrees; save in the case of some large red-blooded fishes, as the tunny, which exceed it in temperature by nearly ten degrees. Among insects, the range is from two to ten degrees above that of the air: the excess varying according to their activity. The heat of reptiles is from four to fifteen degrees more than the heat of their medium. While mammals and birds maintain a heat which continues almost unaffected by external variations, and is often greater than that of the air by seventy, eighty, ninety, and even a hundred degrees. Once more, in greater *self-mobility* a progressive differentiation is traceable. The especial characteristic by which we distinguish dead matter is its inertness: some form of independent motion is our most general test of life. Passing over the indefinite border-land between the animal and vegetal kingdoms, we may roughly class plants as organisms which, while they exhibit that species of motion implied in growth, are not only devoid of locomotive power, but with some unimportant exceptions are devoid of the power of moving their parts in relation to each other; and thus are less differentiated from the inorganic world than animals. Though in those microscopic *Protophyta* and *Protozoa* inhabiting the water—the spores of algæ, the gemmules of sponges, and the infusoria generally—we see locomotion produced by ciliary action; yet this locomotion, while rapid relatively to the size of the creatures, is absolutely slow. Of the *Cœlenterata*, a great part are either permanently rooted or habitually stationary; and so have scarcely any self-mobility but that implied in the relative movements of parts; while the rest, of which the common jelly-fish will serve as a sample, have mostly but little ability to move themselves through the water. Among the higher aquatic *Invertebrata,*—cuttle-fishes and lobsters, for instance,—there is a very considerable power of locomotion; and the aquatic *Vertebrata* are, considered as a class, much more active in their movements than the other inhabitants of the water. But it is only when we come to air-breathing creatures, that we find the vital characteristic of self-mobility manifested in the highest degree. Flying insects, mammals, birds, travel with a velocity far exceeding that attained by any of the lower classes of animals; and so are more strongly contrasted with their inert environment. Thus, on contemplating the various grades of organisms in their ascending order, we find them more and more distinguished from their inanimate media, in *structure*, in *form*, in *chemical composition*, in *specific gravity*, in *temperature*, in *self-mobility*. It is true that this generalization does not hold with complete regularity. Organisms which are in some respects the most strongly contrasted with the environing inorganic world, are in other respects less so than inferior organisms. As a class, mammals are higher than birds; and yet they are of lower temperature, and have smaller powers of locomotion. The stationary oyster is of higher organization than the free-swimming medusa; and the cold-blooded and less heterogeneous fish, is quicker in its movements than the warm-blooded and more heterogeneous sloth. But the admission that the several aspects under which this increasing contrast shows itself, bear variable ratios to each other, does not conflict with the general truth, that as we ascend in the hierarchy of organisms, we meet with not only an increasing differentiation of parts, but also an increasing differentiation from the surrounding medium in sundry other physical attributes. It would seem that this peculiarity has some necessary connexion with superior vital manifestations. One of those lowly gelatinous forms, so transparent and colourless as to be with difficulty distinguished from the water it floats in, is not more like its medium in chemical, mechanical, optical, thermal, and other properties, than it is in the passivity with which it submits to all the influences and actions brought to bear upon it; while the mammal does not more widely differ from inanimate things in these properties, than it does in the activity with which it meets surrounding changes by compensating changes in itself. And between these two extremes, we shall observe a constant ratio between these two kinds of contrast. Whence we may say, that in proportion as an organism is physically like its environment, does it remain a passive partaker of the changes going on in its environment; while in proportion as it is endowed with powers of counteracting such changes, it exhibits greater unlikeness to its environment.*

If now, from this same point of view, we consider the relation borne to its environment by any superior organism in its successive stages, we find an analogous series of contrasts. Of course in respect of degrees of *structure*, the parallelism is complete. The difference, at first small, between the comparatively structureless germ and the comparatively structureless inorganic world, becomes necessarily greater, step by step, as the differentiations of the germ become more numerous and definite. How of *form* the like holds, is equally manifest. The sphere, which is

* This paragraph originally formed part of a review-article on "Transcendental Physiology," published in 1857

from each other, and a differentiation of the consolidated whole from the environment; and that in the last as in the first respect, there is a general analogy between the progression of an individual organism, and the progression from the lowest orders of organisms to the highest orders. It may be remarked that some kinship seems to exist between these generalizations and the doctrine of Schelling, that Life is the tendency to individuation. For evidently, in becoming more distinct from each other, and from their environment, organisms acquire more marked individualities. As far as I can gather from outlines of his philosophy, however, it appears that Schelling entertained this conception in a general and transcendental sense, rather than in a special and scientific one.

§ 54. The deductive interpretations of these general facts of development, in so far as they are at present possible, must be postponed until we arrive at the fourth and fifth divisions of this work; which will be chiefly occupied with them. There are, however, one or two general aspects of these inductions, which may be here most conveniently dealt with deductively.

The general law of development as displayed in organisms, is readily shown to be necessary, if the initial and terminal stages are such as we know them to be. Grant that each organism is at the outset homogeneous, and that when complete it is relatively heterogeneous; and of necessity it follows that development is a change from the homogeneous to the heterogeneous—a change during which there must be gone through all the infinitesimal gradations of heterogeneity that lie between these extremes. If, again, there is at first indefiniteness, and at last definiteness, the transition cannot but be from the one to the other of these, through all intermediate degrees of definiteness. Further, if the parts, originally incoherent or uncombined, eventually become relatively coherent or combined; there must be a continuous increase of coherence or combination. Hence the general truth that development is a change from incoherent, indefinite homogeneity, to coherent, definite heterogeneity, becomes a self-evident one, when observation has shown us the state in which organisms begin, and the state in which they end.

Just in the same way that the growth of an entire organism, is carried on by abstracting from the environment substances like those composing the organism; so the production of each organ within the organism, is carried on by abstracting from the substances contained in the organism, those required by this particular organ. Each organ at the expense of the organism as a whole, integrates with itself certain special kinds and proportions of the matters circulating around it; in the same way that the organism as a whole, integrates with itself certain special kinds and proportions of matters at the expense of the environment as a whole. So that the organs are qualitatively differentiated from each other, in a way analogous to that by which the entire organism is qualitatively differentiated from things around it. Evidently this selective assimilation illustrates the general truth, demonstrable *à priori*, that like units tend to segregate. It illustrates, moreover, the further aspect of this general truth, that the pre-existence of a mass of certain units, produces, probably by polar attraction, a tendency for diffused units of the same kind to aggregate with this mass, rather than elsewhere. It has been shown of particular salts, A and B, co-existing in a solution not sufficiently concentrated to crystallize, that if a crystal of the salt A be put in o the solution, it will increase by uniting with itself the dissolved atoms of the salt A; and that similarly, though there otherwise takes place no deposition of the salt B, yet if a crystal of the salt B is placed in the solution, it will exercise a coercive force on the diffused atoms of this salt, and grow at their expense. No doubt much organic assimilation occurs in the same way. Particular parts of the organism are composed of special units, or have the function of secreting special units, which are ever present in them in large quantities. The fluids circulating through the body contain special units of this same order. And these diffused units are continually being deposited along with the groups of like units that already exist. How purely physical are the causes of this selective assimilation, is, indeed, conclusively shown by the fact, that abnormal constituents of the blood are segregrated in the same way. Cancer-cells having begun to be deposited at a particular place, continue to be deposited at that place. Tubercular matter, making its appearance at particular points, collects more and more round those points. And similarly in numerous pustular diseases. Where the component units of an organ, or some of them, do not exist as such in the circulating fluids, but are formed out of elements or compounds that exist separately in the circulating fluids; it is clear that the process of differential assimilation is of a more complex kind. Still, however, it seems not impossible that it is carried on in an analogous way. If there be an aggregate of compound atoms, each of which contains the constituents A, B, C; and if round this aggregate the constituents A and B and C are diffused in uncombined states; it may be suspected that the coercive polar force of these aggregated compound atoms A, B, C, may not only bring into union with themselves adjacent compound atoms A, B, C, but may cause the adjacent constituents A and B and C to unite into such compound atoms, and then aggregate with the mass. Should this be so, the process of differential assimilation, which plays so important a part in organic development, will not be difficult to understand. At present, however, chemical inquiry appears to have furnished no evidence either for or against such an hypothesis.

sent no distinctions of parts, and nevertheless feed and grow and move about, Prof. Huxley has remarked that they exhibit Life without Organization. The perpetual changes of form which alone distinguish one of these creatures from an inanimate fragment, are no doubt totally irregular and undirected. Still they do, through an average of accidents, subserve the creatures' nutrition; and they do imply an expenditure of force that in some way depends on the consumption of nutriment. They do, therefore, though in the rudest way, display a vital adjustment of internal to external relations.

§ 56. Function falls into divisions of several kinds, according to our point of view. Let us take these divisions in the order of their simplicity.

Under Function in its widest sense, are included both the statical and the dynamical distributions of force which an organism opposes to the forces brought to bear on it. In a tree, the woody core of trunk and branches, and in an animal, the skeleton, internal or external, may be regarded as passively resisting the gravity and momentum which tend habitually or occasionally to derange the requisite relations between the organism and its environment; and since they resist these forces simply by their cohesion, their functions may be classed as *statical*. Conversely, the leaves and sap-vessels in a tree, and those organs which in an animal similarly carry on nutrition and circulation, as well as those which generate and direct muscular motion, must be considered as *dynamical* in their actions. From another point of view, Function is divisible into the *accumulation of force* (latent in food); the *expenditure of force* (latent in the tissues and certain matters absorbed by them); and the *transfer of force* (latent in the prepared nutriment or blood) from the parts which accumulate to the parts which expend. In plants we see little beyond the first of these: expenditure being inappreciable, and transfer required only to facilitate accumulation. In animals, the function of *accumulation* comprehends those processes by which the materials containing latent force are taken in, digested, and separated from other materials; the function of *transfer* comprehends those processes by which these materials, and such others as are needful to liberate the forces they contain, are conveyed throughout the organism; and the function of *expenditure* comprehends those processes by which the forces are liberated from these materials, and transformed into properly co-ordinated motions. Each of these three most general divisions, includes several more special divisions. The accumulation of force may be separated into *alimentation* and *aeration;* of which the first is again separable into the various acts gone through between prehension of food and the transformation of part of it into blood. By the transfer of force is to be understood what we call *circulation;* if the meaning of circulation be extended to embrace the duties of both the vascular system and the lymphatics. Under the head of expenditure of force, come *nervous actions* and *muscular actions:* though not absolutely co-extensive with expenditure, these are almost so. Lastly, there are the subsidiary functions which do not properly fall within any of these general functions, but subserve them by removing the obstacles to their performance: those, namely, of *excretion* and *exhalation*, whereby waste products are got rid of. Again, disregarding their purposes and considering them analytically, the general physiologist may consider functions in their widest sense as the correlatives of tissues—the actions of epidemic tissue, cartilaginous tissue, elastic tissue, connective tissue, osseous tissue, muscular tissue, nervous tissue, glandular tissue. Once more, physiology in its concrete interpretations, recognizes special functions as the ends of special organs—regards the teeth as having the office of mastication; the heart as an apparatus to propel blood; this gland as fitted to produce one requisite secretion and that to produce another; each muscle as the agent of a particular motion; each nerve as the vehicle of a special sensation or a special motor impulse.

It is clear that dealing with Biology only in its larger aspects, specialities of function do not concern us; except in so far as they serve to illustrate, or to qualify, its generalities

§ 57. The first induction to be here set down, is a familiar and obvious one: the induction, namely, that complexity of function, is the correlative of complexity of structure. The leading aspects of this truth must be briefly noted. Where there are no distinctions of structure, there are no distinctions of function. One of the Rhizopods above instanced as exhibiting life without organization, will serve as an illustration. From the outside of this creature, which has not even a limiting membrane, there are protruded numerous thread-like processes. Originating from any point of the surface, each of these may contract again and disappear; or it may touch some fragment of nutriment, which it draws with it, when contracting, into the general mass—thus serving as hand and mouth; or it may come in contact with its fellow-processes at a distance from the body, and become confluent with them; or it may attach itself to an adjacent fixed object, and help by its contraction to draw the body into a new position. In brief, this structureless speck of animated jelly, is at once all stomach, all skin, all mouth, all limb, and doubtless, too, all lung. In organisms having a fixed distribution of parts, there is a concomitant fixed distribution of actions. Among plants we see that when, instead of a uniform tissue like that of the *Algæ*, everywhere devoted to the same process of assimilation, there arise, as in the Exogens, root and stem and leaves, there arise correspondingly unlike processes. Still more conspicuously among animals, do there result varieties of function when the originally homogeneous mass is replaced by hetero-

derm, which absorbs nutriment, and the ectoderm, which, by its own contractions and those of the tentacles it bears, produces motion. That the functions of accumulation and expenditure are here very incompletely distinguished, may be admitted without affecting the position that this is the first specialization which begins to appear. These two most general and most radically-opposed functions, become, in the *Polyzoa*, much more clearly marked-off from each other; at the same time that each of them becomes partially divided into subordinate functions. The endoderm and ectoderm are no longer merely the inner and outer walls of the same simple sac into which the food is drawn; but the endoderm forms a true alimentary canal, separated from the ectoderm by a peri-visceral cavity, containing the nutritive matters absorbed from the food. That is to say, the function of accumulating force is exercised by a part distinctly divided from the part mainly occupied in expending force: the space between them, full of absorbed nutriment, effecting in a vague way that transfer of force which, at a higher stage of evolution, becomes a third leading function. Meanwhile, the endoderm no longer discharges the accumulative function in the same way throughout its whole extent; but its different portions, œsophagus, stomach and intestine, perform different portions of this function. And instead of a contractility uniformly diffused through the ectoderm, there have arisen in it, some parts which have the office of contracting (muscles), and some parts which have the office of making them contract (nerves and ganglia). As we pass upwards, the transfer of force, hitherto effected quite incidentally, comes to have a special organ. In the ascidian mollusca, circulation is produced by a muscular tube, open at both ends, which, by a wave of contraction passing along it, sends out at one end the nutrient fluid drawn in at the other; and which, having thus propelled the fluid for a time in one direction, reverses its movement and propels it in the opposite direction. By such means does this rudimentary heart generate alternating currents in the crude and dilute nutriment occupying the peri-visceral cavity. How the function of transferring force, thus vaguely indicated in these inferior forms, comes afterwards to be the definitely-separated office of a complicated apparatus made up of many parts, each of which has a particular portion of the general duty, need not be described. It is sufficiently manifest that this general function becomes more clearly marked-off from the others, at the same time that it becomes itself parted into subordinate functions

In a developing embryo, the functions or more strictly the structures which are to perform them, arise in the same general order. A like primary distinction very early appears between the endoderm and the ectoderm—the part which has the office of accumulating force, and the part out of which grow those organs that are the great expenders of force Between these two there presently becomes visible the rudiment of that vascular system, which has to fulfil the intermediate duty of transferring force. Of these three general functions, that of accumulating force is carried on from the outset: the endoderm, even while yet incompletely differentiated from the ectoderm, absorbs nutritive matters from the subjacent yelk The transfer of force is also to some extent effected by the rudimentary vascular system, as soon as its central cavity and attached vessels are sketched out But the expenditure of force (in the higher animals at least) is not appreciably displayed by the ectodermic structures that are afterwards to be mainly devoted to it: there is no sphere for the actions of these parts. Similarly with the chief subdivisions of these fundamental functions. If we look at those discharged by the ectoderm, potentially if not actually, we see that the distinction first established separates the office of transforming other force into mechanical motion, from the office of liberating the force to be so transformed—in the midst of the part out of which the muscular system is to be developed, there is marked-out the rudiment of the nervous system. This indication of structures which are to share between them the general duty of expending force, is soon followed by changes that foreshadow further specializations of this general duty. In the incipient nervous system, there begins to arise that contrast between the cerebral mass and the spinal cord, which, in the main, answers to the division of nervous actions into directive and executive; and at the same time, the appearance of vertebral laminæ foreshadows the separation of the osseous system, which has to resist the strains of muscular action, from the muscular system, which, in generating motion, entails these strains. Simultaneously there have been going on similar actual and potential specializations in the functions of accumulating force and transferring force. And throughout all subsequent phases, the method is substantially the same.

This progress from general, indefinite, and simple kinds of action, to special, definite, and complex kinds of action, has been aptly termed by Milne-Edwards, the "physiological division of labour." Perhaps no metaphor can more truly express the nature of this advance from vital activity in its lowest forms to vital activity in its highest forms. And probably the general reader cannot in any other way obtain so clear a conception of functional development in organisms, as he can by tracing out functional development in societies: noting how there first comes a distinction between the governing class and the governed class; how while in the governing class there slowly grow up such differences of duty as the civil, military, and ecclesiastical, there arise in the governed class, fundamentally industrial differences like those between agriculturists and artizans; and how there is a continual multiplication of such specialized occupations, and specialized shares of each occupation.

§ 59. Fully to understand this change from homogeneity to heterogeneity of function, which accompanies the change

the higher mollusca, in which this simple tube is replaced by a system of branched tubes, that deliver their contents through their open ends into the tissues at distant parts; and on coming to those advanced types of animals which have closed arterial and venous systems, ramifying minutely in every corner of every organ; we find that the vascular apparatus, while it has become structurally interwoven with the whole body, has become unable to fulfil its office without the help of offices that are quite separated from its own. The heart is now a complex pump, worked by powerful muscles that are excited by a local nervous system; and the general nervous system also, takes a share in regulating the contractions both of the heart and of all the arteries. On the due discharge of the respiratory function, too, the function of circulation is directly dependent: if the aeration of the blood is impeded, the vascular activity is lowered; and arrest of the one very soon causes stoppage of the other. Similarly with the duties of the nervo-muscular system. Animals of low organization, in which the differentiation and integration of the vital actions have not been carried far, will move about for a considerable time after being eviscerated, or deprived of those appliances by which force is accumulated and transferred. But animals of high organization are instantly killed by the removal of these appliances, and even by the injury of minor parts of them: a dog's movements are suddenly brought to an end, by cutting one of the main canals along which the materials that evolve movements are conveyed. Thus while in well-developed creatures the distinction of functions is very marked, the combination of functions is very close. From instant to instant, the aeration of blood implies that certain respiratory muscles are being made to contract by certain nerves; and that the heart is duly propelling the blood to be aerated. From instant to instant digestion proceeds only on condition that there is a supply of aerated blood, and a due current of nervous energy through the digestive organs. That the heart may act, it must from instant to instant be excited by discharges from certain ganglia; and the discharges from these ganglia are made possible, only by the conveyance to them, from instant to instant, of the blood which the heart propels.

It is not easy to find an adequate expression for this double re-distribution of functions. It is not easy to realize a transformation through which the functions thus become in one sense separated and in another sense combined, or even interfused. Here, however, as before, an analogy drawn from social organization helps us. If we observe how the increasing division of labour in societies, is accompanied by a closer co-operation; and how the agencies of different social actions, while becoming in one respect more distinct, become in another respect more minutely ramified through each other; we shall understand better the increasing physiological co-operation that accompanies increasing physiological division of labour. Note, for example, that while local divisions and classes of the community have been growing unlike in their several occupations, the carrying on of their several occupations has been growing dependent on the due activity of that vast organization by which sustenance is collected and diffused. During the early stages of social development, every small group of people, and often every family, obtained separately its own necessaries; but now, for each necessary, and for each superfluity, there exists a combined body of wholesale and retail distributors, which brings its branched channels of supply within reach of all. While each citizen is pursuing a business that does not immediately aim at the satisfaction of his personal wants, his personal wants are satisfied by a general agency that brings from all places commodities for him and his fellow-citizens —an agency which could not cease its special duties for a few days, without bringing to an end his own special duties and those of most others. Consider, again, how each of these differentiated functions is everywhere pervaded by certain other differentiated functions. Merchants, manufacturers, wholesale distributors of their several species, together with lawyers, bankers, &c., all employ clerks. In clerks we have a specialized class dispersed through various other classes; and having its function fused with the different functions of these various other classes. Similarly commercial travellers, though having in one sense a separate occupation, have in another sense an occupation forming part of each of the many occupations which it aids. As it is here with the sociological division of labour, so is it with the physiological division of labour above described. Just as we see in an advanced community, that while the magisterial, the clerical, the medical, the legal, the manufacturing, and the commercial activities, have grown distinct, they have yet their agencies mingled together in every locality; so in a developed organism, we see that while the general functions of circulation, secretion, absorption, excretion, contraction, excitation, &c., have become differentiated, yet through the ramifications of the systems apportioned to them, they are closely combined with each other in every organ.

§ 60. The physiological division of labour, is usually not carried so far as wholly to destroy the primary physiological community of labour. As in societies the adaptation of special classes to special duties, does not entirely disable these classes from performing each others' duties on an emergency; so in organisms, tissues and structures that have become fitted to the particular offices they have ordinarily to discharge, often remain partially able to discharge other offices. It has been pointed out by Dr Carpenter, that "in cases where the different functions are highly specialised, the general structure retains, more or less, the primitive community of function which originally characterized it." A few instances will bring home this generalization

The roots and leaves of plants are widely differenti-

arms and legs do, when needful, fulfil, to some extent, each others' offices. Not only in childhood and old age are the arms used for purposes of support, but on occasions of emergency, as when mountaineering, they are so used by men in full vigour. And that legs are to a considerable degree capable of performing the duties of arms, is proved by the great amount of manipulatory skill reached by them when the arms are absent. Among the perceptions, too, there are examples of partial substitution. The deaf Dr Kitto described himself as having become excessively sensitive to vibrations propagated through the body; and as so having gained the power of perceiving, through his general sensations, those neighbouring concussions of which the ears ordinarily give notice. Blind people make hearing perform, in part, the office of vision. Instead of identifying the positions and sizes of neighbouring objects by the reflection of light from their surfaces, they do this in a rude way by the reflection of sound from their surfaces.

We see, as we might expect to see, that this power of performing more general functions, is great in proportion as the parts have been but little adapted to their special functions. In the hydra, where complete transposition of functions is possible, the histological differentiation that has been established, is extremely slight, or even inappreciable. Those parts of plants which show so considerable a power of discharging each others' offices, are not widely unlike in their minute structures. And the tissues that in animals are to some extent mutually vicarious, are tissues in which the original cellular composition is still conspicuous. But we do not find evidence that the muscular, nervous, or osseous tissues are able in any degree to perform those processes which the less differentiated tissues perform. Nor have we any proof that nerve can partially fulfil the duty of muscle, or muscle that of nerve. We must say, therefore, that the ability to resume the primordial community of function, varies inversely as the established specialization of function; and that it disappears when the specialization of function becomes great.

§ 61. Something approaching to *à priori* reasons may be given for the conclusions thus reached *à posteriori*. They must be accepted for as much as they seem worth.

It may be argued that on the hypothesis of Evolution, Life necessarily comes before organization. On this hypothesis, organic matter in a state of homogeneous aggregation, must precede organic matter in a state of heterogeneous aggregation. But since the passing from a structureless state to a structured state, is itself a vital process, it follows that vital activity must have existed while there was yet no structure: structure could not else arise. That function takes precedence of structure, seems also implied in the definition of Life. If Life consists of inner actions so adjusted as to balance outer actions—if the actions are the *substance* of Life, while the adjustment of them constitutes its *form*; then, may we not say that the actions to be formed must come before that which forms them—that the continuous change which is the basis of function, must come before the structure which brings function into shape? Or again, since throughout all phases of Life up to the highest, every advance is the effecting of some better adjustment of inner to outer actions; and since the accompanying new complexity of structure is simply a means of making possible this better adjustment; it follows that function is from beginning to end the determining cause of structure. Not only is this manifestly true where the modification of structure arises by reaction from modification of function; but it is also true where a modification of structure otherwise produced, apparently initiates a modification of function. For it is only when such so-called spontaneous modification of structure subserves some advantageous action, that it is permanently established: if it is a structural modification that happens to facilitate the vital activities, "natural selection" retains and increases it; but if not, it disappears.

The connexion which we noted between heterogeneity of structure and heterogeneity of function—a connexion made so familiar by experience as to appear scarcely worth specifying—is clearly a necessary one. It follows from the general truth that in proportion to the heterogeneity of any aggregate, is the heterogeneity it will produce in any incident force (*First Principles*, § 116). The force continually liberated in the organism by decomposition, is here the incident force; the functions are the variously modified forms produced in its divisions by the organs they pass through; and the more multiform the organs the more multiform must be the differentiations of the force passing through them.

It follows obviously from this, that if structure progresses from the homogeneous, indefinite, and incoherent, to the heterogeneous, definite, and coherent, so too must function. If the number of different parts in an aggregate must determine the number of differentiations produced in the forces passing through it—if the distinctness of these parts from each other, must involve distinctness in their reactions, and therefore distinctness between the divisions of the differentiated force; there cannot but be a complete parallelism between the development of structure and the development of function. If structure advances from the simple and general to the complex and special, function must do the same.

from prolonged abstinence. Even fish, though much more active than most other aquatic creatures, appear to undergo but little loss of substance when kept unfed during considerable periods. Reptiles, too, maintaining no great temperature, and passing their lives mostly in a state of torpor, suffer but little diminution of mass by waste. When, however, we turn to those higher orders of animals which are active and hot-blooded, we see that waste is rapid: producing when unchecked, a notable decrease in bulk and weight, ending very shortly in death. Besides finding that waste is inconsiderable in creatures that produce but little insensible and sensible motion, and that it becomes conspicuous in creatures that produce much insensible and sensible motion; we find that in the same creatures there is most waste when most motion is generated. This is clearly proved by hybernating animals. "Valentin found that the waking marmot excreted in the average 75 times more carbonic acid, and inhaled 41 times more oxygen than the same animal in the most complete state of hybernation. The stages between waking and most profound hybernation yielded intermediate figures. A waking hedgehog yielded about 20·5 times more carbonic acid, and consumed 18·4 times more oxygen than one in the state of hybernation." If we take these quantities of absorbed oxygen and excreted carbonic acid, as indicating something like the relative amounts of consumed organic substance, we see that there is a striking contrast between the waste accompanying the ordinary state of activity, and the waste accompanying complete quiescence and reduced temperature. This difference is still more definitely shown by the fact, that the mean daily loss from starvation in rabbits and guinea-pigs, bears to that from hybernation, the proportion of 18·3 : 1. Among men and domestic animals, the relation between degree of waste and amount of expended force, though one respecting which there is little doubt, is less distinctly demonstrable; since waste is not allowed to go on uninterfered with. We have however in the lingering lives of invalids who are able to take scarcely any nutriment, but are kept warm and still, an illustration of the extent to which waste diminishes as the expenditure of force declines.

Besides the connexion between the waste of the organism as a whole, and the production of sensible and insensible motion by the organism as a whole; there is a traceable connexion between the waste of special parts and the activities of such special parts. Experiments have shown that "the starving pigeon daily consumes in the average 40 times more muscular substance than the marmot in the state of torpor, and only 11 times more fat, 33 times more of the tissue of the alimentary canal, 18·3 times more liver, 15 times more lung, 5 times more skin." That is to say, in the hybernating animal the parts least consumed are the almost totally quiescent motor-organs, and the part most consumed is the hydro-carbonaceous deposit serving as a store of force; whereas in the pigeon, similarly unsupplied with food but awake and active, the greatest loss takes place in the motor-organs. The relation between special activity and special waste, is illustrated too in the daily experiences of all: not indeed in the measurable decrease of the active parts in bulk or weight, for this we have no means of ascertaining; but in the diminished ability of such parts to perform their functions. That legs exerted for many hours in walking, and arms long strained in rowing, lose their powers—that eyes become enfeebled by reading or writing without intermission—that concentrated attention unbroken by rest, so prostrates the brain as to incapacitate it for thinking; are familiar truths. And though we have no direct evidence to this effect, there is little danger in concluding that muscles exercised until they ache or become stiff, and nerves of sense rendered weary or obtuse by work, are organs so much wasted by action as to be partially incompetent.

Repair is everywhere and always making up for waste Though the two processes vary in their relative rates, both are constantly going on. Though during the active, waking state of an animal, waste is in excess of repair, yet repair is in progress; and though during sleep, repair is in excess of waste, yet some waste is necessitated by the carrying on of certain never-ceasing functions. The organs of these never-ceasing functions furnish, indeed, the most conclusive proofs of the simultaneity of repair and waste. Day and night the heart never stops beating, but only varies in the rapidity and vigour of its beats; and hence the loss of substance which its contractions from moment to moment entail, must from moment to moment be made good. Day and night the lungs dilate and collapse; and the muscles which make them do this, must therefore be ever kept in a state of integrity by a repair which keeps pace with waste, or which alternately falls behind and gets in advance of it to a very slight extent.

On a survey of the facts, we see, as we might expect to see, that repair is most rapid when activity is most reduced. Assuming that the organs which absorb and circulate nutriment are in proper order, the restoration of the organism to a state of integrity, after the disintegration consequent on expenditure of force, is proportionate to the diminution in expenditure of force. Thus we all know that those who are in health, feel the greatest return of vigour after profound sleep—after complete cessation of motion. We know that a night during which the quiescence, bodily and mental, has been less decided, is usually not followed by that spontaneous overflow of energy that indicates a high state of efficiency throughout the organism. We know, again, that long-continued recumbency, even with wakefulness (providing the wakefulness is not the result of disorder), is followed by a certain renewal of strength; though a renewal less than that which would have followed the greater inactivity of slumber. We know, too, that when exhausted by labour, sitting brings a partial return of vigour. And we also know that after the violent exertion of running,

After gazing at a bright light of a particular colour, we see on turning the eyes to adjacent objects, an image of the complementary colour; showing that the retina has, for the moment, lost the power to feel small amounts of those rays which have strongly affected it. Such inabilities disappear in a few seconds or a few minutes, according to circumstances. And here, indeed, we are introduced to a conclusive proof that special repair is ever neutralizing special waste. For the rapidity with which the eyes recover their sensitiveness, varies with the reparative power of the individual. In youth, the visual apparatus is so quickly restored to its state of integrity, that many of these *photogenes*, as they are called, cannot be perceived. When sitting on the far side of a room, and gazing out of the window against a light sky, a person who is debilitated by disease or advancing years, perceives, on transferring the gaze to the adjacent wall, a momentary negative image of the window—the sash-bars appearing light and the squares dark; but a young and healthy person has no such experience. With a rich blood and vigorous circulation, the repair of the visual nerves after impressions of moderate intensity, is nearly instantaneous.

Function carried to excess, may produce waste so great, that repair cannot make up for it during the ordinary daily periods of rest; and there may result incapacities of the overtaxed organs, lasting for considerable periods. We know that eyes strained by long-continued minute work, lose their power for months or years: perhaps suffering an injury which they never wholly recover. Brains, too, are often so unduly worked that permanent relaxation fails to restore them to vigour. Even of the motor organs the like holds. The most frequent cause of what is called "wasting palsy," or atrophy of the muscles, is habitual excess of exertion: the proof being, that the disease occurs most frequently among those engaged in laborious handicrafts, and usually attacks first the muscles that have been most worked.

There has yet to be noticed another kind of repair;—that namely, by which injured or lost parts are restored. Among the *Hydrozoa* it is common for any portion of the body to reproduce the rest; even though the rest to be so reproduced is the greater part of the whole. In the more highly-organized *Actinozoa*, the half of an individual will grow into a complete individual. Some of the lower Annelids, as the *Nais*, may be cut into thirty or forty pieces, and each piece will eventually become a perfect animal. As we ascend to higher forms, we find this reparative power much diminished, though still considerable. The reproduction of a lost claw by a lobster or crab, is a familiar instance. Some of the inferior *Vertebrata* also, as lizards, can develop new limbs or new tails, in place of those that have been cut off; and can even do this several times over, though with decreasing completeness. The highest animals, however, thus repair themselves to but a very small extent. Mammals and birds do it only in the healing of wounds; and very often but imperfectly even in this. For in muscular and glandular organs, the tissues destroyed are not properly reproduced, but are replaced by tissue of an irregular kind, which serves to hold the parts together. So that the power of reproducing lost parts is greatest where the organization is lowest; and almost disappears where the organization is highest. And though we cannot say that between these extremes there is a constant inverse relation between reparative power and degree of organization; yet we may say that there is some approach to such a relation.

§ 63. There is a very obvious and complete harmony between the first of the above inductions, and the deduction that follows immediately from first principles. We have already seen (§ 23) "that whatever amount of power an organism expends in any shape, is the correlate and equivalent of a power that was taken into it from without." Motion, sensible or insensible, generated by an organism, is insensible motion which was absorbed in producing certain chemical compounds appropriated by the organism under the form of food. As much power as was required to raise the elements of these complex atoms to their state of unstable equilibrium, is given out in their falls to a state of stable equilibrium; and having fallen to a state of stable equilibrium, they can give out no further power, but have to be got rid of as inert and useless. It is an inevitable corollary "from the persistence of force, that each portion of mechanical or other energy which an organism exerts, implies the transformation of as much organic matter as contained this energy in a latent state;" and that this organic matter in yielding up its latent energy, loses its value for the purposes of life, and becomes waste matter needing to be excreted. The loss of these complex unstable substances must hence be proportionate to the quantity of expended force. Here then is the rationale of certain general facts lately indicated. Plants do not waste to any considerable degree, for the obvious reason that the sensible and insensible motions they generate are inconsiderable. Between the small waste, small activity, and low temperature of the inferior animals, the relation is similarly one admitting of *à priori* establishment. Conversely, the rapid waste of energetic, hot-blooded animals might be foreseen with equal certainty. And not less manifestly necessary is the variation in waste which, in the same organism, attends the variation in the heat and mechanical motion produced.

Between the activity of a special part and the waste of that part, a like relation may be deductively inferred; though it cannot be inferred that this relation is equally definite. Were the activity of every organ quite independent of the activities of other organs, we might expect to trace out this relation distinctly; but since one part of the force which any organ expends, is derived from materials brought to it by the blood from moment to moment in quantities varying with the demand, and since another part of the force which such organ expends, comes to it in the shape of

and, if recovery ensue, the blood will seem to have returned to its previous condition: yet it is not as it was before; for now the same poison may be added to it with impunity." * * * "The change once effected, may be maintained through life. And herein seems to be a proof of the assimilative force in the blood; for there seems no other mode of explaining these cases than by admitting that the altered particles have the power of assimilating to themselves all those by which they are being replaced: in other words, all the blood that is formed after such a disease deviates from the natural composition, so far as to acquire the peculiarity engendered by the disease: it is formed according to the altered model." Now if the compound molecules of the blood, or of an organism considered in the aggregate, have the power of moulding into their own type, the matters which they absorb as nutriment; and if, as Mr Paget points out, they have the power when their type has been changed by disease, of moulding all materials afterwards received into the modified type; may we not reasonably suspect that the more or less specialized molecules of each organ, have, in like manner, the power of moulding the materials which the blood brings to them, into similarly specialized molecules? The one conclusion seems to be a corollary from the other. Such a power cannot be claimed for the component units of the blood, without being conceded to the component units of every tissue. Indeed the assertion of this power is little more than an assertion of the fact, that organs composed of specialized units *are* capable of resuming their structural integrity, after they have been wasted by function. For if they do this, they must do it by forming from the materials brought to them, certain specialized units like in kind to those of which they are composed, and to say that they do this, is to say that their component units have the power of moulding fit materials into other units of the same order.

The repair of a wasted tissue may therefore be considered as due to forces analogous to those by which a crystal reproduces its lost apex, when placed in a solution like that from which it was formed. In either case, a mass of units of a given kind, shows a power of integrating with itself diffused units of the same kind: the only difference being, that the organic mass of units arranges the diffused units into special compound forms, before integrating them with itself. In the case of the crystal, this reintegration is ascribed to polarity—a power of whose nature we know nothing. Whatever be its nature, however, it appears probable that the power by which organs repair themselves from the nutritive matters circulating through them, is of the same order.

§ 65. That other kind of repair which shows itself in the regeneration of lost members, is comprehensible only as an effect of actions like those just referred to. The ability of an organism to recomplete itself when one of its parts has been cut off, is of the same order as the ability of an injured crystal to recomplete itself. In either case, the newly-assimilated matter is so deposited as to restore the original outline. And if in the case of the crystal, we say that the whole aggregate exerts over its parts, a force which constrains the newly-integrated atoms to take a certain definite form; we must in the case of the organism, assume an analogous force. This is, in truth, not an hypothesis: it is nothing more than a generalized expression of the facts. If when the leg of a lizard has been amputated, there presently buds out the germ of a new one, which, passing through phases of development like those of the original leg, eventually assumes a like shape and structure; we assert nothing more than what we see, when we assert that the organism as a whole exercises such power over the newly-forming limb, as makes it a repetition of its predecessor. If a leg is reproduced where there was a leg, and a tail where there was a tail; we have no alternative but to conclude that the aggregate forces of the body, control the formative processes going on in each part. And on contemplating these facts in connexion with various kindred ones, there is suggested the hypothesis, that the form of each species of organism is determined by a peculiarity in the constitution of its units—that these have a special structure in which they tend to arrange themselves; just as have the simpler units of inorganic matter. Let us glance at the evidences which more especially thrust this conclusion upon us.

A fragment of a Begonia-leaf, imbedded in fit soil and kept at an appropriate temperature, will develop a young Begonia; and so small is the fragment which is thus capable of originating a complete plant, that something like a hundred plants might be produced from a single leaf. The friend to whom I owe this observation, tells me that various succulent plants have like powers of multiplication. Illustrating a similar power among animals, we have the often-cited experiments of Trembley on the common polype. Each of the four pieces into which one of these creatures was cut, grew into a perfect individual. In each of these again, bisection and tri-section effected a like result. And so with their segments, similarly produced, until as many as fifty polypes had resulted from the original one. Bodies when cut off regenerated heads; heads regenerated bodies; and when a polype had been divided into as many pieces as was practicable, nearly every piece survived and became a complete animal. What, now, is the implication? We cannot say that in each portion of a Begonia-leaf, and in every fragment of a Hydra's body, there exists a ready-formed model of the entire organism. Even were there warrant for the now abandoned doctrine, that the germ of every organism contains the perfect organism in miniature, it still could not be contended that each considerable part of the perfect organism resulting from such a germ, contains another such miniature. Indeed the one hypothesis obviously negatives the other. We have therefore no alternative but to say, that the living particles composing one of these fragments, have an innate tendency to arrange themselves into

care, however, to restrict its meaning. If we simply substitute the term polarity, for the circuitous expression—the power which certain units have of arranging themselves into a special form, we may, without assuming anything more than is proved, use the term organic polarity or polarity of the organic units, to signify the proximate cause of the ability which organisms display of reproducing lost parts.

§ 66. As we shall have frequent occasion hereafter to refer to these units, which possess the property of arranging themselves into the special structures of the organisms to which they belong; it will be well here to ask what these units are, and by what name they may be most fitly called.

On the one hand, it cannot be in those proximate chemical compounds composing organic bodies, that this specific polarity dwells. It cannot be that the atoms of albumen, or fibrine, or gelatine, or the hypothetical protein-substance, possess this power of aggregating into specific shapes; for in such case, there would be nothing to account for the unlikenesses of different organisms. Millions of species of plants and animals, more or less contrasted in their structures, are all mainly built up of these complex atoms. But if the polarities of these atoms determined the forms of the organisms they composed, the occurrence of such endlessly varied forms would be inexplicable. Hence, what we may call the *chemical units*, are clearly not the possessors of this property.

On the other hand, this property cannot reside in what may be roughly distinguished as the *morphological units*. The germ of every organism is a microscopic cell. It is by multiplication of cells that all the early developmental changes are effected. The various tissues which successively arise in the unfolding organism, are primarily cellular; and in many of them the formation of cells continues to be, throughout life, the process by which repair is carried on. But though cells are so generally the ultimate visible components of organisms, that they may with some show of reason be called the morphological units; yet, as they are not universal, we cannot say that this tendency to aggregate into specified forms dwells in them. Finding that in many cases a fibrous tissue arises out of a structureless blastema, without cell-formation; and finding that there are creatures, such as Rhizopods, which are not cellular, but nevertheless exhibit vital activities, and perpetuate in their progeny certain specific distinctions; we are forbidden to ascribe to cells this peculiar power of arrangement. Nor, indeed, were cells universal, would such an hypothesis be acceptable; since the formation of a cell is, to some extent a manifestation of this same peculiar power.

If, then, this organic polarity can be possessed neither by the chemical units nor the morphological units, we must conceive it as possessed by certain intermediate units, which we may term *physiological*. There seems no alternative but to suppose, that the chemical units combine into units immensely more complex than themselves, complex as they are; and that in each organism, the physiological units produced by this further compounding of highly compound atoms, have a more or less distinctive character. We must conclude that in each case, some slight difference of composition in these units, leading to some slight difference in their mutual play of forces, produces a difference in the form which the aggregate of them assumes.

The facts contained in this chapter, form but a small part of the evidence which thrusts this assumption upon us. We shall hereafter find various reasons for inferring that such physiological units exist, and that to their specific properties, more or less unlike in each plant and animal, various organic phenomena are due.

CHAPTER V.

ADAPTATION.

§ 67. In plants, waste and repair being scarcely appreciable, there are not likely to arise appreciable changes in the proportions of already-formed parts. The only divergences from the average structure of a species, which we may expect particular conditions to produce, are those producible by the action of these conditions on parts in course of formation; and such divergences we do find. We know that a tree which, standing alone in an exposed position, has a short and thick stem, has a tall and slender stem when it grows in a wood; and that its branches then take a different inclination. We know that potato-sprouts which, on reaching the light, develop into foliage, will, in the absence of light, grow to a length of several feet without foliage. And every in-door plant furnishes proof, that shoots and leaves, by habitually turning themselves to the light, exhibit a certain adaptation—an adaptation due, as we must suppose, to the special effects of the special conditions on the still growing parts. In animals, however, besides analogous structural changes wrought during the period of growth, by subjection to circumstances unlike the ordinary circumstances; there are structural changes similarly wrought, after maturity has been reached. Organs that have arrived at their full size, possess a certain modifiability; so that while the organism as a whole, retains pretty

hands, find that such an exercise as rowing, soon begins to produce a like thickening. This relation of cause and effect is still better shown by the marked indurations at the ends of a violinist's fingers. Even in mucous membrane, which ordinarily is not subject to mechanical forces of any intensity, similar modifications are possible: witness the callosity of the gums which arises in those who have lost their teeth, and have to masticate without teeth. The vascular system furnishes good instances of the increased growth that follows increased function. When, because of some permanent obstruction to the circulation, the heart has to exert a greater contractile force on the mass of blood which it propels at each pulsation into the arteries, and when there results the laboured action known as palpitation; there usually occurs dilatation, or hypertrophy, or a mixture of the two: the dilatation, which is a yielding of the heart's structure under the increased strain, implying a failure to meet the emergency; but the hypertrophy, which consists in a thickening of the heart's muscular walls, being an adaptation of it to the additional effort required. Again, when an aneurism in some considerable artery has been obliterated, either artificially or by a natural inflammatory process; and when this artery has consequently ceased to be a channel for the blood; some of the adjacent arteries which anastomose with it, become enlarged, so as to carry the needful quantity of blood to the parts supplied. Though we have no direct proof of analogous modifications in nervous structures; yet indirect proof is given by the greater efficiency that follows greater activity. This is manifested alike in the senses and the intellect. The palate may be cultivated into extreme sensitiveness, as in professional tea-tasters. An orchestral conductor gains by continual practice, an unusually great ability to discriminate differences of sound. And in the finger-reading of the blind, we have evidence that the sense of touch may be brought by exercise to a far higher capability than is ordinary. The increase of power which habitual exertion gives to mental faculties, needs no illustration: every person of education has personal experience of it. Even from the osseous structures, evidence may be drawn. The bones of men accustomed to great muscular action, are more massive and have more strongly marked processes for the attachment of muscles, than the bones of men who lead sedentary lives; and a like contrast holds between the bones of wild and tame animals of the same species. Adaptations of another order, in which there is a qualitative rather than a quantitative modification, arise after certain accidents to which the skeleton is liable. When the hip-joint has been dislocated, and long delay has made it impossible to restore the parts to their proper places, the head of the thigh-bone, imbedded in the surrounding muscles, becomes fixed in its new position by attachments of fibrous tissue, which afford support enough to permit a halting walk. But the most remarkable modification of this order occurs in ununited fractures. "False joints" are often formed—joints which rudely simulate the hinge structure or the ball-and-socket structure, according as the muscles tend to produce a motion of flexion and extension or a motion of rotation. In the one case, according to Rokitansky, the two ends of the broken bone become smooth and covered with periosteum and fibrous tissue, and are attached by ligaments that allow a certain backward and forward motion; and in the other case, the ends, similarly clothed with the appropriate membranes, become the one convex and the other concave, are inclosed in a capsule, and are even occasionally supplied with synovial fluid!

The general truth that extra function is followed by extra growth, must be supplemented by the equally general truth, that beyond a limit, usually soon reached, very little, if any, further modification can be produced. The experiences from which we draw the one induction thrust the other upon us. After a time, no training makes the pugilist or the athlete any stronger. The adult gymnast at last acquires the power to perform certain difficult feats; but certain more difficult feats, no additional practice enables him to perform. Years of discipline give the singer a particular loudness and range of voice, beyond which further discipline does not give greater loudness or wider range: on the contrary, increased vocal exercise, causing a waste in excess of repair, is often followed by decrease of power. In the perceptions we see similar limits. The culture which exalts the susceptibility of the ear to the intervals and harmonics of notes, will not turn a bad ear into a good one. Life-long effort fails to make this artist a correct draftsman, or that a fine colourist: each does better than he did at first, but each falls short of the power attained by some other artists. Nor is this truth less clearly illustrated among the more complex mental powers. Each man has a mathematical faculty, a poetical faculty, or an oratorical faculty, which special education improves to a certain extent. But unless he is unusually endowed in one of these directions, no amount of education will make him a first-rate mathematician, a first-rate poet, or a first-rate orator. Thus the general fact appears to be, that while in each individual, certain changes in the proportions of parts, may be caused by variations of function, the congenital structure of each individual puts a limit to the modifiability of every part. Nor is this true of individuals only: it holds, in a sense, of species. Leaving open the question whether, in indefinite time, indefinite modification may not be produced; experience proves that within assigned times, the changes wrought in races of organisms by changes of conditions fall within narrow limits. We see, for instance, that though by discipline, aided by selective breeding, one variety of horse has had its locomotive power increased considerably beyond the locomotive powers of other varieties; yet that further increase takes place, if at all, at an inappreciable rate. The different kinds of dogs, too, in which different forms and capacities have been established, do not show aptitudes for diverging in the same directions at

capacity produced, to a very considerable degree, even after a long period of desistance; but one who has persevered in such habits for but a short time, has, at the end of a like period, scarcely any of the facility he had gained. Here, too, as before, successions of organisms present an analogous fact. A species in which domestication, continued through many generations, has organized certain peculiarities; and which afterwards, escaping domestic discipline, returns to something like its original habits; soon loses, in great measure, such peculiarities. Though it is not true, as alleged, that it resumes completely the structure it had before domestication; yet it approximates to that structure. The Dingo, or wild dog of Australia, is one of the instances given of this; and the wild horse of South America is another. Mankind, too, supplies us with instances. In the Australian bush, and in the backwoods of America, the Anglo-Saxon race, in which civilization has developed the higher feelings to a considerable degree, rapidly lapses into comparative barbarism: adopting the moral code, and sometimes the habits, of savages.

§ 68. It is important to reach, if possible, some rationale of these general truths—especially of the last two. A right understanding of these laws of organic modification, underlies a right understanding of the great question of species. While, as before hinted (§ 40), the action of structure on function, is one of the factors in that process of differentiation by which unlike forms of plants and animals are produced, the re-action of function on structure, is another factor. Hence, it is well worth while inquiring how far these inductions are deductively interpretable.

The first of them is the most difficult to deal with. Why an organ exerted somewhat beyond its wont, should presently grow, and thus meet increase of demand by increase of supply, is not obvious. We know, indeed, (*First Principles*, §§ 96, 133,) that of necessity, the rhythmical changes produced by antagonist organic actions, cannot any of them be carried to an excess in one direction, without there being produced an equivalent excess in the opposite direction. It is a corollary from the persistence of force, that any deviation effected by a disturbing cause, acting on some member of a moving equilibrium, must (unless it altogether destroys the moving equilibrium) be eventually followed by a compensating deviation. Hence, that excess of repair should succeed excess of waste, is to be expected. But how happens the mean state of the organ to be changed? If daily extra waste naturally brings about daily extra repair, only to an equivalent extent, the mean state of the organ should remain constant. How then comes the organ to augment in size and power?

Such answer to this question as we may hope to find, must be looked for in the effects wrought on the organism as a whole, by increased function in one of its parts. For since the discharge of its function by any part, is possible only on condition that those various other functions on which its own is immediately dependent, are also discharged; it follows that excess in its function presupposes some excess in their functions. Additional work given to a muscle, implies additional work given to the branch arteries which bring it blood, and additional work, smaller in proportion, to the arteries from which these branch arteries come. Similarly, the smaller and larger veins which take away the blood, as well as the absorbents which carry off effete products, must have more to do. And yet further, on the nervous centres which excite the muscle, a certain extra duty must fall. But excess of waste will entail excess of repair, in these parts as well as in the muscle. The several appliances by which the nutrition and excitation of an organ are carried on, must also be influenced by this rhythm of action and re-action; and therefore, after losing more than usual by the destructive process, they must gain more than usual by the constructive process. But temporarily-increased efficiency in these appliances by which blood and nervous force are brought to an organ, will cause extra assimilation in the organ, beyond that required to balance its extra expenditure. Regarding the functions as constituting a moving equilibrium, we may say, that divergence of any function in the direction of increase, causes the functions with which it is bound up to diverge in the same direction; that these again cause the functions which they are bound up with, also to diverge in the same direction; and that these divergences of the connected functions, allow the specially-affected function to be carried further in this direction than it could otherwise be—further than the perturbing force could carry it if it had a fixed basis.

It must be admitted that this is but a vague explanation. Among actions so involved as these, we can scarcely expect to do more than dimly discern a harmony with first principles. That the facts are to be interpreted in some such way, may, however, be inferred from the circumstance that an extra supply of blood continues for some time to be sent to an organ that has been unusually exercised; and that when unusual exercise is long continued, a permanent increase of vascularity results.

§ 69. Answers to the questions—Why do these adaptive modifications in an individual animal, soon reach a limit? and why, in the descendants of such animal, similarly conditioned, is this limit very slowly extended?—are to be found in the same direction as was the answer to the last question. And here the connexion of cause and consequence is much more manifest.

Since the function of any organ is dependent on the functions of the organs which supply it with materials and forces; and since the functions of these subsidiary organs are dependent on the functions of organs which supply them with materials and forces; it follows that before any great extra power of discharging its function, can be gained by a

essentially like re-action of functions on structures. From the laws of adaptive modification in societies, we may therefore hope to get a clue to the laws of adaptive modification in organisms. Let us suppose, then, that a society has arrived at a state of equilibrium like that of a mature animal—a state not like our own, in which growth and structural development are rapidly going on; but a state of settled balance among the functional powers of the various classes and industrial bodies, and a consequent fixity in the relative sizes of such classes and bodies. Further, let us suppose that in a society thus balanced, there occurs something which throws an unusual demand on some one industry—say an unusual demand for ships (which we will assume to be built of iron) in consequence of a competing mercantile nation having been prostrated by famine or pestilence. The immediate result of this additional demand for iron ships, is the employment of more workmen, and the purchase of more iron, by the ship-builders; and when, presently, the demand continuing, the builders find their premises and machinery insufficient, they enlarge them. If the extra requirement persists, the high interest and high wages bring such extra capital and labour into the business, as are needed for new ship-building establishments. But such extra capital and labour do not come quickly; since, in a balanced community, not increasing in population and wealth, labour and capital have to be drawn from other industries, where they are already yielding the ordinary returns. Let us now go a step further. Suppose that this iron-ship-building industry, having enlarged as much as the available capital and labour permit, is still unequal to the demand; what limits its immediate further growth? The lack of iron. By the hypothesis, the iron-producing industry, like all the other industries throughout the community, yields only as much iron as is habitually required for all the purposes to which iron is applied: ship-building being only one. If, then, extra iron is required for ship-building, the first effect is to withdraw

and labour from other investments and occupations. And until the permanent extra demand for coal, has become great enough to draw from other investments and occupations, sufficient capital and labour to sink new mines, the increasing production of iron must be restricted by the scarcity of coal; and the multiplication of ship-yards and ship-builders, must be checked by the want of iron. Thus, in a community which has reached a state of moving equilibrium, though any one industry directly affected by an additional demand, may rapidly undergo a small extra growth; yet a growth beyond this, requiring, as it does, the building-up of subservient industries, less directly and strongly affected, as well as the partial unbuilding of other industries, can take place only with comparative slowness. And a still further growth, requiring structural modifications of industries still more distantly affected, must take place still more slowly.

Returning from this analogy, we realize more clearly the truth, that any considerable member of an animal organism, cannot be greatly enlarged without some general re-organization. Besides a building-up of the primary, secondary, and tertiary groups of subservient parts, there must be an unbuilding of sundry non-subservient parts;—or at any rate, there must be permanently established, a lower nutrition of such non-subservient parts. For it must be remembered that in a mature animal, or one which has reached a balance between assimilation and expenditure, there cannot be an increase in the nutrition of some organs, without a decrease in the nutrition of others; and an organic establishment of the increase, implies an organic establishment of the decrease—implies more or less change in the processes and structures throughout the entire system. And here, indeed, is disclosed one reason why growing animals undergo adaptations so much more readily than adult ones. For while there is surplus nutrition, it is possible for specially-exercised parts to be specially enlarged, without any positive

occupations, and the new yards would be devoted to other uses. But if the increased need for ships lasted long enough, and became great enough, to cause a flow of capital and labour from other industries into the iron-manufacture, a falling off in the demand for ships, would much less rapidly entail a dwindling of the ship-building industry. For iron being now produced in greater quantity, a diminished consumption of it for ships, would cause a fall in its price, and a consequent fall in the cost of ships: thus enabling the ship-builders to meet the competition which we may suppose led to a decrease in the orders they received. And since, when new blast-furnaces and rolling-mills, &c., had been built with capital drawn from other industries, its transference back into other industries, would involve great loss; the owners, rather than transfer it, would accept unusually low interest; and an excess of iron would continue to be produced; resulting in an undue cheapness of ships, and a maintenance of the ship-building industry at a size beyond the need. Eventually, however, if the number of ships required still diminished, the production of iron in excess would become very unremunerative: some of the blast-furnaces would be blown out; and as much of the capital and labour as remained available, would be re-distributed among other occupations. Without repeating the steps of the argument, it will be clear that were the enlargement of the ship-building industry great enough, and did it last long enough, to cause an increase in the number of coal-mines; the ship-building industry would be still better able to maintain itself under adverse circumstances; but that it would, though at a more distant period, end by sinking down to the needful dimensions. Thus our conclusions are:—First, that if the extra activity and growth of a particular industry, has lasted long enough only to remodel the proximately-affected industries; it will dwindle away again after a moderate period, if the need for it disappears. Second, that an enormous period must be required before the re-actions produced by an enlarged industry, can cause a re-construction of the whole society, and before the countless re-distributions of capital and labour, can again reach a state of equilibrium. And third, that only when such a new state of equilibrium is eventually reached, can the adaptive modification become a permanent one. How, in animal organisms, the like argument will hold, needs not be pointed out. The reader will readily follow the parallel.

That organic types should be comparatively stable, might be anticipated on the hypothesis of Evolution. If we assume, as we must according to this hypothesis, that the structure of any organism is a product of the almost infinite series of actions and re-actions to which all ancestral organisms have been exposed; we shall see that any unusual actions and re-actions brought to bear on an individual, can have but an infinitesimal effect in permanently changing the structure of the organism as a whole. The new set of forces, compounded with all the antecedent sets of forces, can but inappreciably modify that moving equilibrium of functions which all these antecedent sets of forces have established. Though there may result a considerable perturbation of certain functions—a considerable divergence from their ordinary rhythms; yet the general centre of equilibrium cannot be sensibly changed. On the removal of the perturbing cause, the previous balance will be quickly restored: the effect of the new forces being almost obliterated by the enormous aggregate of forces which the previous balance expresses.

§ 71. As thus understood, the phenomena of adaptation fall into harmony with first principles. The inference that organic types are fixed, because the deviations from them which can be produced within assignable periods, are relatively small; and because, when a force producing deviation ceases, there is a return to something like the original state; proves to be an invalid inference. Without assuming fixity of species, we find good reasons for anticipating that kind and degree of stability which is observed. We find grounds for concluding, *à priori*, that an adaptive change of structure, will soon reach a point beyond which further adaptation will be slow; for concluding that when the modifying cause has been but a short time in action, the modification generated, will be evanescent; for concluding that a modifying cause acting even for many generations, will do but little towards permanently altering the organic equilibrium of a race; and for concluding that on the cessations of such cause, its effects will become unapparent in the course of a few generations.

specific peculiarities. Shall we regard all the growing axes thus resulting from slips and grafts and buds, as parts of one individual, or as distinct individuals? If a strawberry-plant sends out runners carrying buds at their ends, which strike root and grow into independent plants, that separate from the original one by decay of the runners, must we not say that they possess separate individualities; and yet if we do this, are we not at a loss to say when their separate individualities were established, unless we admit that each bud was from the beginning an individual? Commenting on such perplexities, Schleiden says—"Much has been written and disputed concerning the conception of the individual, without, however, elucidating the subject, principally owing to the misconception that still exists as to the origin of the conception. Now the individual is no conception, but the mere subjective comprehension of an actual object, presented to us under some given specific conception, and on this latter it alone depends whether the object is or is not an individual. Under the specific conception of the solar system, ours is an individual: in relation to the specific conception of a planetary body, it is an aggregate of many individuals." * * * "I think, however, that looking at the indubitable facts already mentioned, and the relations treated of in the course of these considerations, it will appear most advantageous and most useful, in a scientific point of view, to consider the vegetable cell as the general type of the plant (simple plant of the first order). Under this conception, *Protococcus* and other plants consisting of only one cell, and the spore and pollen-granule, will appear as individuals. Such individuals may, however, again, with a partial renunciation of their individual independence, combine under definite laws into definite forms (somewhat as the individual animals do in the globe of the *Volvox globator**). These again appear empirically as individual beings, under a conception of a species

* It is now generally agreed that the *Volvox globator* is a plant.

(simple plants of the second order) derived from the form of the normal connexion of the elementary individuals. But we cannot stop here, since nature herself combines these individuals, under a definite form, into larger associations, whence we draw the third conception of the plant, from a connexion, as it were, of the second power (compound plants —plants of the third order). The simple plant proceeding from the combination of the elementary individuals is then termed a bud (*gemma*), in the composition of plants of the third order."

The animal kingdom presents still greater difficulties. When, from sundry points on the body of a common polype, there bud-out young polypes, which, after acquiring mouths and tentacles and closing up the communications between their stomachs and the stomach of the parent, finally separate from the parent; we may with propriety regard them as distinct individuals. But when, in the allied compound *Hydrozoa*, we find that these young polypes continue permanently connected with the parent; and when, by this continuous budding-out, there is presently produced a tree-like aggregation, having a common alimentary canal into which the digestive cavity of each polype opens; it is no longer so clear that these little sacs furnished with mouths and tentacles, are severally to be regarded as distinct individuals. We cannot deny a certain individuality to the polypedom. And on discovering that some of the buds, instead of unfolding in the same manner as the rest, are transformed into capsules in which eggs are developed—on discovering that certain of the incipient polypes thus become wholly dependent on the aggregate for their nutrition, and discharge functions which have nothing to do with their own maintenance, we have still clearer proof that the individualities of the members are partially merged in the individuality of the group. Other organisms belonging to the same order, display still more decidedly this transition from simple individualities to a complex individuality. In the *Diphyes* there is a special modification of one or more members of the polypedom into a swimming apparatus, which, by its rhythmical contractions, propels itself through the water, drawing the polypedom after it. And in the more differentiated *Physalia*, various organs result from the metamorphosis of parts that are the homologues of individual polypes. In this last instance, the individuality of the aggregate is so predominant, that the individualities of the members are practically lost. This combination of individualities in such way as to produce a composite individual, meets us in other forms among the ascidian molluscs. While in some of these, as in the *Clavelina*, the animals associated are but little subordinated to the community they form; in others, as in the *Botryllidæ*, they are so fused into a rounded mass, as to present the appearance of a single animal with several mouths and stomachs.

On the hypothesis of Evolution, perplexities of this nature are just such as we might anticipate. If Life in general, commenced with minute and simple forms, like those out of which all individual organisms, however complex, now originate; and if the transitions from these primordial units to organisms made up of groups of such units, and to higher organisms made up of groups of such groups, took place by degrees; it is clear that individualities of the first and simplest order, would merge gradually in those of a larger and more complex order, and these again in others of an order having still greater bulk and organization; and that hence it would be impossible to say where the lower individualities ceased, and the higher individualities commenced.

§ 73. To meet these difficulties, it has been proposed that the whole product of a single fertilized germ, shall be regarded as a single individual: whether such whole product be organized into one mass, or whether it be organized into many masses, that are partially or completely separate. It is urged that whether the development of the fertilised germ

organism; and yet, though an individual according to the definition, this organism has no power of reproducing its kind. On the other hand, we have cases like that of the perfect *Aphides*, where the organism is but an infinitesimal part of the germ-product; and yet has that completeness required for sexual reproduction. Moreover, if we adopt the proposed view, we find ourselves committed to the anomalous position, that among many orders of animals, there are no concrete individuals at all. If the individual is constituted by the whole germ-product, whether continuously or discontinuously developed, then, not only must individuality be denied to each of the imperfect *Aphides*, but also to each of the perfect males and females; since no one of them is more than a minute fraction of the total germ-product. And yet further, it might be urged with some show of reason, that if the conception of individuality involves the conception of completeness; then, an organism which possesses an independent power of reproducing itself, being more complete than an organism in which this power is dependent on the aid of another organism, is more individual.

§ 74. There is, indeed, as already implied, no definition of individuality that is unobjectionable. All we can do is to make the best practicable compromise.

As applied either to an animate or an inanimate object, the word individual ordinarily connotes union among the parts of the object, and separateness from other objects. This fundamental element in the conception of individuality, we cannot with propriety ignore in the biological application of the word. That which we call an individual plant or animal, must, therefore, be some concrete whole, and not a discrete whole. If, however, we say that each concrete living whole is to be regarded as an individual, we are still met by the question—What constitutes a concrete living whole? A young organism arising by internal or external gemmation from a parent organism, passes gradually from a state in which it is an indistinguishable part of the parent organism, to a state in which it is a separate organism of like structure with the parent. At what stage does it become an individual? And if its individuality be conceded only when it completely separates from the parent, must we deny individuality to all organisms thus produced, which permanently retain their connexions with their parents? Or again, what must we say of the *Hectocotylus*, which is an arm of the Cuttle-fish that undergoes a special development, and then detaching itself, lives independently for a considerable period? And what must we say of that larval *Echinus*, which is left to move about awhile after being robbed of its viscera by the young *Echinus* developed within it?

To answer such questions, we must revert to the definition of Life. The distinction between individual in its biological sense, and individual in its more general sense, must consist in the manifestation of Life, properly so called. Life we have seen to be, "the definite combination of heterogeneous changes, both simultaneous and successive, in correspondence with external co-existences and sequences." Hence, a biological individual is any concrete whole having a structure which enables it, when placed in appropriate conditions, to continuously adjust its internal relations to external relations, so as to maintain the equilibrium of its functions. In pursuance of this conception, we must consider as individuals, all those wholly or partially independent organized masses, which arise by multicentral and multiaxial development that is either continuous or discontinuous (§ 50). We must accord the title to each separate aphis, each polype of a polypedom, each bud or shoot of a flowering plant, whether it detaches itself as a bulbil or remains attached as a branch.

By thus interpreting the facts, we do not, indeed, avoid all anomalies. While, among flowering plants, the power of independent growth and development, is usually possessed only by shoots or axes; yet, in some cases, as in that of the Begonia-leaf awhile since mentioned, the appendage of an axis, or even a small fragment of such appendage, is capable of initiating and carrying on the functions of life; and in other cases, as shown by M. Naudin in the *Drosera intermedia*, young plants are occasionally developed from the surfaces of leaves, while still connected with the parent plant. Nor among forms like the compound *Hydrozoa*, does the definition enable us to decide where the line is to be drawn between the individuality of the group and the individualities of the members—merging into each other, as these do, in different degrees. But, as before said, such difficulties must necessarily present themselves, if organic forms have arisen by insensible gradations. We must be content with a course which commits us to the smallest number of incongruities; and this course is, to consider as an individual, any centre or axis that is capable of independently carrying on that continuous adjustment of inner to outer relations which constitutes Life.

the same form. These two distinct processes of multiplication, may be aptly termed *homogenesis* and *heterogenesis*.* Under these heads let us consider them more closely.

The kind of genesis, once supposed to be universal, in which the successive generations are alike, is always sexual genesis; or, as it has been otherwise called—*gamogenesis*. In every species of organism which multiplies by homogenesis, each generation consists of males and females; and from the fertilized germs they produce, the next generation of similar males and females arises. This method of propagation is further distinguished by the peculiarity, that each fertilized germ gives rise to but one individual—the product of development is always organized round one axis, and not round several axes. Between the different kinds of homogenesis, the most marked contrast, and the only one which need here detain us, is that between the oviparous and the viviparous. The oviparous kind is that in which the fertilized germ is detached from the parent, before it has undergone any considerable development. The viviparous kind is that in which development is considerably advanced, or almost completed, before final detachment takes place. This distinction is, however, not a sharply-defined one: there are transitions between the oviparous and the viviparous processes. In ovo-viviparous genesis, there is an internal incubation; and though the young are in this case finally detached from the parent in the shape of eggs, they do not leave the parent's body until after they have assumed something like the parental form. Looking around, we find that homogenesis is universal among the *Vertebrata*: there is no known vertebrate animal but what arises from a fertilized germ, and unites into its single individuality the whole products of this fertilized germ. In

* Unfortunately the word *heterogenesis*, has been already used as a synonyme for "spontaneous generation." Save by those few who believe in "spontaneous generation," however, little objection will be felt to using the word in a sense that seems much more appropriate.

the mammals or highest *Vertebrata*, this homogenesis is in every case viviparous; in birds it is uniformly oviparous; and in reptiles and fishes, it is always essentially oviparous, though there are cases, of the kind above referred to, in which viviparity is simulated. Passing to the *Invertebrata*, we find oviparous homogenesis universal among the *Arachnida* (except the Scorpions, which are ovo-viviparous); universal among the higher *Crustacea*, but not among the lower; extremely general, though not universal, among Insects; and universal among the higher *Mollusca*, though not among the lower. Along with extreme inferiority among animals, we find homogenesis to be the exception rather than the rule; and in the vegetal kingdom, there appear to be no cases, save those of a few aberrant parasites like the *Rafflesiaceæ*, in which the centre or axis which arises from a fertilized germ, becomes the immediate producer of fertilized germs.

Where propagation is carried on by heterogenesis, or is characterized by unlikeness of the successive generations, there is always asexual genesis with occasionally-recurring sexual genesis; in other words—*agamogenesis* interrupted more or less frequently by *gamogenesis*. If we set out with a generation of perfect males and females; then, from their ova or seeds, there arise individuals that are neither males nor females, but that produce the next generation from buds. By this method of multiplication, many individuals originate from a single fertilized germ: the product of development is organized round more than one centre or axis. The simplest form of heterogenesis is that seen in uniaxial plants. If, as we find ourselves obliged to do, we regard each separate shoot or axis of growth, as a distinct individual; then, in uniaxial plants, the successive individuals are not represented by the series A, A, A, A, &c., like those resulting from homogenesis; but they are represented by the series A, B, A, B, A, B, &c. For in plants which were before classed as uniaxial (§ 50), and which may be conveniently so distinguished from other plants, the axis which shoots up from the seed, and substantially constitutes the plant, does not itself flower and bear seed; but gives lateral origin to flowering, or seed-bearing, axes. Though in uniaxial plants, the fructifying apparatus *appears* to be at the end of the primary, vertical axis; yet dissection shows that, morphologically considered, each fructifying axis is usually an offspring from the primary axis. There arises from the seed, a sexless individual, from which spring by gemmation, individuals having reproductive organs; and from these there result fertilized germs or seeds, that give rise to sexless individuals. That is to say, gamogenesis and agamogenesis alternate: the peculiarity being, that the sexual individuals arise from the sexless ones by continuous development. The *Salpa* show us an allied form of heterogenesis in the animal kingdom. Individuals developed from fertilised ova, instead of themselves producing fertilized ova, produce, by gemmation, strings of individuals; from which fertilised ova again originate. In multiaxial plants, we have a succession of generations represented by the series A, B, B, B, &c., A, B, B, B, &c. Supposing A to be a flowering axis, or sexual individual; then, from any fertilized germ it casts off, there grows up a sexless individual, B; from this there bud-out other sexless individuals, B; and so on for generations more or less numerous; until at length, from some of these sexless individuals, there bud-out seed-bearing individuals of the original form A. Branched herbs, shrubs, and trees, exhibit this form of heterogenesis: the successive generations of sexless individuals thus produced, being in most cases continuously developed, or aggregated into a compound individual; but being in some cases discontinuously developed. Among animals, a kind of heterogenesis represented by the same succession of letters, occurs in such compound polypes as the *Sertularia;* and in those of the *Hydrozoa* which assume alternately the polypoid form, and the form of the *Medusa:* the chief differences

word; but rather, as they have since been called by Prof. Huxley, pseud-ova. Von Siebold and other naturalists, have hence applied the term parthenogenesis to a narrower class of cases. Perhaps it would be best to distinguish this process, which is intermediate between metagenesis and parthenogenesis, by the term *pseudo-parthenogenesis*. It is the process familiarly exemplified in the *Aphides*. Here, from the fertilized eggs laid by perfect females, there grow up imperfect females, in the pseud-ovaria of which there are developed pseud-ova; and these, rapidly assuming the organization of other imperfect females, are born viviparously. From this second generation of imperfect females, there by and by arises, in the same manner, a third generation, of the same kind; and so on for many generations: the series being thus symbolized by the letters A, B, B, B, B, B, &c., A. Respecting this kind of heterogenesis, it should be added, that in animals, as in plants, the number of generations of sexless individuals produced before the re-appearance of sexual ones, is indefinite; both in the sense that in the same species it may go on to a greater or less extent according to circumstances, and in the sense that among the generations of individuals proceeding from the same fertilized germ, a recurrence of sexual individuals takes place earlier in some of the diverging lines of multiplication than in others. In trees we see that on some branches, flower-bearing axes arise while other branches are still producing only leaf-bearing axes; and in the successive generations of *Aphides*, a parallel truth has been observed. Lastly has to be set down, that form of heterogenesis in which, along with gamogenesis, there occurs a form of agamogenesis exactly like it, save in the absence of fecundation. This is called true parthenogenesis—reproduction carried on by virgin mothers, which are in all respects like other mothers. In the silk-worm-moths this parthenogenesis is exceptional, rather than ordinary: usually the eggs of these insects are fertilized; but if they are not, they are still laid, and some of them produce larvæ. In certain *Lepidoptera*, however, of the groups *Psychidæ* and

Tineidæ, parthenogenesis appears to be a normal process—indeed, so far as is known, the only process; for of some species the males have never been found.

A general conception of the relations among the different modes of Genesis, thus briefly described, will be best given by the following tabular statement.

GENESIS is
- Homogenesis, which is Gamogenesis
  - Oviparous or Ovo-viviparous or Viviparous
- or
- Heterogenesis, which is
  - Gamogenesis alternating with Agamogenesis
    - Parthenogenesis or Pseudo-parthenogenesis or Metagenesis
      - Internal or External

This, like all other classifications of such phenomena, presents anomalies. It may be justly objected, that the processes here grouped under the head agamogenesis, are the same as those before grouped under the head of discontinuous development (§ 50): thus making development and genesis partially coincident. Doubtless it seems awkward that what are from one point of view considered as structural changes, are from another point of view considered as modes of multiplication.*

* Prof. Huxley avoids this difficulty by making every kind of Genesis a mode of development. His classification, which suggested the one given above, is as follows:—

Development
- Continuous
  - Growth
  - Metamorphosis
- Discontinuous
  - Agamogenesis
    - Metagenesis
    - Parthenogenesis
  - Gamogenesis

There is, however, nothing for us but a choice of imperfections. We cannot by any logical dichotomies, accurately express relations which, in Nature, graduate into each other insensibly. Neither the above, nor any other scheme, can do more than give an approximate idea of the truth.

§ 76. Genesis under every form, is a process of negative or positive disintegration; and is thus essentially opposed to that process of integration, which is one element of individual evolution. Negative disintegration occurs in those cases where, as among the compound *Hydrozoa*, there is a continuous development of new individuals by budding from the bodies of older individuals; and where the older individuals are thus prevented from growing to a greater size, or reaching a higher degree of integration. Positive disintegration occurs in those cases of agamogenesis where the formation of new individuals is discontinuous, and in all cases of gamogenesis. The degrees of disintegration are various. At the one extreme, the parent organism is completely broken up, or dissolved into new individuals; and at the other extreme, the new individual forms but a small deduction from the parent organism. *Protozoa* and *Protophyta*, show us that form of disintegration called spontaneous fission: two or four individuals being produced by the splitting-up of the original one. The *Volvox* and the *Hydrodictyon*, are plants which, having developed broods of young plants within themselves, give them exit by bursting; and among animals, the one lately referred to, which arises from the *Distoma* egg, entirely loses its individuality in the individualities of the numerous *Distoma*-larvæ with which it becomes filled. Speaking generally, the degree of disintegration becomes less marked, as we approach the higher organic forms. Plants of advanced types throw off from themselves, whether by gamogenesis or agamogenesis, parts that are relatively small; and among the higher animals, there is no case in which the parent individuality is habitually

separated from the parent-plant under the shape of a centre; and the embryo-cell, though not absolutely separated from the parent, is still no longer subordinate to the organizing forces of the parent. So that when, the embryo-cell having been fertilized by matter from the pollen-tube, the development commences; it proceeds without parental control: the new individual, though remaining physically united with the old individual, becomes structurally and functionally separate while still only a centre of development; and takes on its axial form by processes of its own—the old individual doing no more than supply materials. Throughout the animal kingdom, the new individuals produced by gamogenesis, are obviously separated in the shape of centres of development wherever the reproduction is oviparous. the only conspicuous variation being in the quantity of nutritive matter bequeathed by the parent to the new centre of development, at the time of its separation. And though, where the reproduction is viviparous, the process appears to be different, and in one sense is so; yet, intrinsically, it is the same. For in these cases, the new individual really detaches itself from the parent while still only a centre of development; but instead of being finally cast off in this state, it is re-attached, and supplied with nutriment until it assumes a more or less complete axial structure.

§ 77. Under all its various forms, the essential act in gamogenesis, is the union of two centres or cells, produced by different parent organisms: the sperm-cell being the male product, and the germ-cell the female. There are very many modes and modifications of modes in which these cells are produced; very many modes and modifications of modes by which they are brought into contact; and very many modes and modifications of modes by which the resulting fertilized germs have secured to them the fit conditions for their development. But passing over these many divergent and re-divergent kinds of sexual multiplication, which it would take too much space here to specify, the one universal peculiarity which it concerns us to remark, is, this coalescence of a detached portion of one organism, with a more or less detached portion of another.

Such protophytes as the *Palmellæ* and the *Desmidieæ*, which are sometimes distinguished as unicellular plants, show us a coalescence, not of detached portions of two organisms, but of two entire organisms: in the *Palmellæ*, conjugation is a complete fusion of the individuals; and in the *Desmidieæ*, the entire contents of the individuals unite to form the germ-mass. Where, as among the *Confervæ*, we have aggregated cells whose individualities are scarcely at all subordinate to that of the aggregate, the gamogenetic act is effected by the union of the contained granules of two adjacent cells. In *Spirogyra*, it is not adjacent cells in the same thread which thus combine; but cells of one thread with those of another. As we ascend to plants of high organization, we find that the two reproductive elements become quite distinct in their characters; and further, that they arise in different organs set apart for their production: the arrangements being such, that the sperm-cells of one plant combine with the germ-cells of another.

There is reason to think that, among the lowest *Protozoa*, a fusion of two individualities, analogous to that which occurs in the conjugation of certain *Algæ*, is the process from which results the germ of a new series of individuals. But in animals formed by the aggregation of units that are homologous with *Protozoa*, the sperm-cells and germ-cells are differentiated. And even in these humble forms, where there is no differentiation of sexes, we have good evidence that, as in all higher forms, the union is not between sperm-cells and germ-cells that have arisen in the same individual; but between those that have arisen in different individuals.

The marvellous phenomena initiated by the meeting of sperm-cell and germ-cell, naturally suggest the conception of some quite special and peculiar properties possessed by these cells. It seems obvious that this mysterious power which they display, of originating a new and complex organism, distinguishes them in the broadest way from portions of organic substance in general. Nevertheless, the more we study the evidence, the more is this assumption shaken—the more are we led towards the conclusion, that these cells have not been made by some unusual elaboration, fundamentally different from all other cells. The first fact which points to this modified conclusion, is the fact recently dwelt upon (§ 63), that in many plants and inferior animals, a small fragment of tissue that is but little differentiated, is capable of developing into the form of the organism from which it was taken. Conclusive proof obliged us to admit, that the component units of organisms, have inherent powers of arranging themselves into the forms of the organisms to which they belong. And if to these component units, which we distinguished as physiological, such powers must be conceded—if, under fit conditions, and when not much specialised, they manifest such powers in a way as marked as that in which the contents of sperm-cells and germ-cells manifest them; then, it becomes clear that the properties of sperm-cells and germ-cells are not so peculiar as we are apt to assume. Again, the organs for preparing sperm-cells and germ-cells, have none of the speciality of structure which might be looked for, did sperm-cells and germ-cells need endowing with properties essentially unlike those of all other organic agents. On the contrary, these reproductive centres proceed from tissues that are characterized by their low organization. In plants, for example, it is not appendages that have acquired considerable structure, which produce the fructifying particles: these arise at the extremities of the axes, where the degree of structure is the least. The embryo-cells are formed in the undifferentiated part of the cambium-layer; the pollen-grains are formed at the little-differentiated extremities of the stamens; and both are homologous with simple epithelium-cells. Among many

specialized, but rather that they are unspecialized: such specializations as some of them exhibit in the shape of locomotive appliances, &c., being interpretable not as intrinsic, but as extrinsic, modifications, that have reference to nothing beyond certain mechanical requirements. Sundry facts tend likewise to show, that there does not exist the profound distinction which we are apt to assume, between the male and female reproductive elements. In the common polype, sperm-cells and germ-cells are developed in the same layer of indifferent tissue; and in *Tethya*, one of the sponges, Prof. Huxley has observed that they occur mingled together in the general parenchyma. The pollen-grains and embryo-cells of plants, arise in adjacent parts of the cambium-layer; and from a description of a monstrosity in the Passion-flower, recently given by Mr Salter to the Linnæan Society, it appears, both that ovules may, in their general structure, graduate into anthers, and that they may produce pollen in their interiors. All which evidence is in perfect harmony with the foregoing conclusion; since, if sperm-cells and germ-cells have natures not essentially unlike those of unspecialized cells in general, their natures cannot be essentially unlike each other.

The next general fact to be noted, is, that these cells whose union constitutes the essential act of gamogenesis, are cells in which the developmental changes have come to a close—cells which, however favourably circumstanced in respect of nutrition, are incapable of further evolution. Though they are not, as many cells are, unfitted for growth and metamorphosis by being highly specialized; yet they have lost the power of growth and metamorphosis. They have severally reached a state of equilibrium. And while the internal balance of forces prevents a continuance of constructive changes, it is readily overthrown by external destructive forces. For it uniformly happens that sperm-cells and germ-cells which are not brought in contact, disappear. In a plant, the embryo-cell, if not fertilized, is absorbed or dissipated, while the ovule aborts; and the unimpregnated ovum eventually decomposes.

Such being the characters of these cells, and such being their fates if kept apart, we have now to observe what happens when they are united. For a long time, the immediate sequence of their contact was not ascertained. This is at length, however, decided. It has been shown that in plants, the extremity of the elongated pollen-cell applies itself to the surface of the embryo-sac, but does not enter the embryo-sac. In animals, however, the process is different. Careful observers agree, that the spermatozoon passes through the limiting membrane of the ovum. The result in both cases is presumed to be a mixture of the contents of the two cells. The evidence goes to show that in plants, matter passes by osmose from the pollen-cell into the embryo-cell; and that in animals, the substance contained in the spermatozoon becomes mingled with the substance contained in the ovum, either by simple diffusion or by cell-multiplication. But the important fact which it chiefly concerns us to notice, is, that on the union of these reproductive elements, there begins, either at once or on the return of favourable conditions, a new series of developmental changes. The state of equilibrium at which each of them had arrived, is destroyed by their mutual influence; and the constructive changes which had come to a close, recommence: a process of cell-multiplication is set up; and the resulting cells presently begin to aggregate into the rudiment of a new organism.

Thus, passing over the variable concomitants of gamogenesis, and confining our attention to what is constant in it, we see:—that there is habitually, if not universally, a fusion of two portions of organic substance, which are either themselves distinct individuals, or are thrown off by distinct individuals; that these portions of organic substance, which are severally distinguished by their low degree of specialization, have arrived at states of structural quiescence or equilibrium; that if they are not united, this equilibrium ends in dissolution; but that by the mixture of them, this equilibrium is destroyed, and a new evolution initiated.

§ 78. What are the conditions under which Genesis takes place? How does it happen that some organisms multiply by homogenesis, and others by heterogenesis? Why is it that where agamogenesis prevails, it is usually from time to time interrupted by gamogenesis? These are questions of extreme interest; but questions to which decisive answers cannot yet be given. In the existing state of Biology, we must be content if we can learn the direction in which answers lie. A survey of the facts, discloses certain correlations which, if not universal, are too general to be without significance.

Where the multiplication of individuals is carried on by heterogenesis, we find, in numerous cases, that agamogenesis continues as long as the forces which result in growth, are greatly in excess of the antagonistic forces. While conversely, we find that the recurrence of gamogenesis, takes place when the conditions are no longer so favourable to growth. In like manner, where there is homogenetic multiplication, new individuals are usually not formed while the preceding individuals are still rapidly growing—that is, while the forces producing growth exceed the opposing forces to a great extent; but the formation of new individuals begins when nutrition is nearly equalled by expenditure. To specify all the facts that seem to warrant these inductions, would take more space than can be here spared. A few of them must suffice.

The relation between fructification and innutrition, among plants, was long ago asserted by a German biologist—by Wolff, I am told. When, some years ago, I met with the assertion, I was not acquainted with the evidence on which it rested. Since that time, however, I have, when occasion favoured, examined into the facts for myself. The result has been a conviction, strengthened by every further inquiry,

structure of the sexual axis, affords corroborative evidence: giving very much the impression, as it does, of an aborted sexless axis. Besides lacking those internodes which the leaf-bearing axis commonly possesses, the flowering axis differs by the absence of rudimentary lateral axes. In a leaf-bearing axis, the axil of every leaf usually contains a small bud, which may or may not develop into a lateral axis; but though the petals of a flower are homologous with leaves, they do not bear homologous buds at their bases. Ordinarily, too, the foliar appendages of sexual axes, are much smaller than those of sexless ones—the stamens and pistils especially, which are the last formed, being extremely dwarfed; and there is even reason for thinking that the absence of chlorophyll from the parts of fructification, is a fact of like meaning. Moreover, the formation of the seed-vessel appears to be a direct consequence of arrested nutrition. If a gloved-finger be taken to represent a growing shoot, (the finger standing for the core of the shoot, and the glove for the cambium-layer, in which the process of growth takes place); and if it be supposed that there is a diminished supply of material for growth; then, it seems a fair inference, that growth will first cease at the apex of the cambium-layer, represented by the end of the glove-finger; and supposing growth to continue in those parts of the cambium-layer that are nearer to the supply of nutriment, their further longitudinal extension will lead to the formation of a cavity at the extremity of the shoot, like that which results in a glove-finger when the finger is partially withdrawn and the glove sticks to its end. Whence it seems,

with bract, but much smaller than the other; corolla large but cleft along the top; six stamens with anthers, pistil, and seed-vessel. 3rd flower, large; six-cleft calyx, cleft corolla, with six stamens, pistil, and seed-vessel, with a second pistil half unfolded at its apex. 4th flower, large; divided along the top, six stamens. 5th flower, large; corolla divided into three parts, six stamens. 6th flower, large; corolla cleft, calyx six-cleft, the rest of the flower normal. 7th, and all succeeding flowers, normal.

both that this introversion of the cambium-layer may be considered as due to failing nutrition, and that the ovules growing from its introverted surface (which would have been its outer surface but for the defective nutrition) are extremely aborted homologues of external appendages—either leaves or lateral axes: the essential organs of fructification thus arising where the defective nutrition has reached its extreme.* To all which let us not forget to add, that the sperm-cells and germ-cells are formed at the very ends of the organs of fructification.

Those kinds of animals which multiply by heterogenesis, present us with a parallel relation between the recurrence of gamogenesis and the recurrence of conditions unfavourable to growth—at least, this is shown where experiments have thrown light on the connexion of cause and effect; namely, among the *Aphides*. These creatures, hatched from eggs in the spring, multiply by agamogenesis throughout the summer. When the weather becomes cold, and plants no longer afford abundant sap, perfect males and females are produced; and from gamogenesis there result fertilized ova. But now observe that beyond this evidence, we have much more conclusive evidence. For it has been shown, both that the rapidity of the agamogenesis is proportionate to the warmth and nutrition, and that if the temperature and

* It appears that botanists do not agree respecting the homologies of the ovules: some thinking that they are rudimentary foliar organs, and others that they are rudimentary axial organs. Possibly the dispute will prove a bootless one; since there seems evidence that ovules may be transformed into either one or the other. Mr Salter's paper, lately referred to, shows that they may graduate into stamens, which are foliar organs; and the case of the Foxglove, which I have described above, shows that they may develop into flower-buds, which are axial organs. I would venture to suggest, that the conflicting evidence can be reconciled, only by regarding ovules as the homologues of lateral appendages; and considering a lateral appendage as composed of a leaf, plus a rudimentary axis, either of which may abort. This is the view which seems countenanced by development; since, in its first stage, a lateral bud, whence a lateral appendage arises, shows no division into rudimentary leaf and rudimentary axis; and it is to the lateral bud in this first stage, that the seed-bud or ovule is homologous.

in each ovarium, amounts, under favourable circumstances, to as many as eight or nine; while of the gamic eggs, only one at a time is produced in each ovarium, and occasionally one of the ovaria produces none: whence it follows, that as the gamic egg is not more than twice the bulk of the agamic egg, the quantity of matter contained in an agamic brood, is four times, and occasionally even eight times, as great as that contained in a gamic brood. Thus the quantity of nutriment expended in gamogenesis during a given period (making allowance for that which goes to the formation of the ephippium), is far less than that expended in agamogenesis during a like period. Seeing, then, this constant preparation for either gamic or agamic genesis, in a creature liable to such irregular variations of nutrition; and seeing that the agamogenesis implies by its amount, a large excess of nutrition, while the gamogenesis implies by its amount, a small excess of nutrition; we can scarcely doubt that the one or the other mode of multiplication occurs, according as the external conditions are or are not favourable to nutrition.

Passing now to animals which multiply by homogenesis—animals in which the whole product of a fertilized germ aggregates round a single centre or axis, instead of round many centres or axes; we see, as before, that so long as the conditions allow rapid increase in the mass of this germ-product, the formation of new individuals by gamogenesis does not take place. Speaking generally, we find that only when growth is declining in relative rapidity, do perfect sperm-cells and germ-cells begin to appear; and that the fullest activity of the reproductive function, arises as growth ceases—speaking generally, we must say, because, though this relation is tolerably definite in the highest orders of animals which multiply by gamogenesis, it is less definite in the lower orders. This admission does not militate against the hypothesis, as it seems to do; for the indefiniteness of the relation occurs where the limit of growth is comparatively indefinite. We saw (§ 46) that among active, hot-blooded creatures, such as mammals and birds, the inevitable balancing of assimilation by expenditure, establishes, for each species, an almost uniform adult size; and among creatures of these kinds, (birds especially, in which this restrictive effect of expenditure is most conspicuous), the connexion between cessation of growth and commencement of reproduction, is distinct. But we also saw (§ 46) that where, as in the Crocodile and the Pike, the conditions and habits of life are such, that expenditure does not overtake assimilation as the size increases, there is no precise limit of growth; and in creatures thus circumstanced, we may naturally look for a comparatively indeterminate relation between declining growth and commencing reproduction.* There is, indeed, among fishes, at least one case which appears very anomalous. The male parr, or young of the male salmon, a fish of four or five inches in length, is said to produce milt. Having, at this early stage of its growth, not one hundredth of the weight of a full-grown salmon, how does its production of milt consist with the alleged general law? The answer must be in a great measure hypothetical. If the salmon is (as it appears in its young state) a species of fresh-water trout, that has contracted the habit of annually migrating to the sea, where it finds a food on which it thrives—if the original size of this species was not much greater than that of the parr (which is nearly as large as some varieties of lake-trout and river-trout)—and if the limit of growth in the trout tribe is very indefinite, as we know it to be; then we may reasonably infer, that the parr has nearly the adult form and size of this species of trout, before it acquired its migratory habit; and that this production of milt, is,

* I owe to Mr Lubbock an important confirmation of this view. After stating his belief, that between Crustaceans and Insects, there exists a physiological relation analogous to that which exists between water-vertebrata and land-vertebrata; he pointed out to me, that while among Insects, there is a definite limit of growth, and an accompanying definite commencement of reproduction, among Crustaceans, where growth has no definite limit, there is no definite relation between the commencement of reproduction and the decrease or arrest of growth.

in such case, a concomitant of the incipient decline of growth naturally arising in the species, when living under the conditions of its remote ancestors. If this be admitted, the immense subsequent growth of the parr into the salmon, must be regarded as due to a suddenly-increased facility in obtaining food—a facility which removes to a great distance the limit at which assimilation is balanced by expenditure; and which has the effect, analogous to that produced in plants, of arresting the incipient reproductive process, and causing a resumption of growth. A confirmation of this view may be drawn from the fact, that when the parr, after its first migration to the sea, returns to fresh water, having increased in a few months from a couple of ounces to five or six pounds, it no longer shows any fitness for propagation: the grilse, or immature salmon, does not produce milt or spawn. But without citing further illustrations, or attempting to meet further difficulties, it has, I think, been made sufficiently clear, that some such connexion as that alleged, exists. Traversed, as is this relation between commencement of sexual reproduction and declining rate of growth, by various other relations, it is quite as manifest as we can expect it to be.

The general law to which both homogenesis and heterogenesis conform, thus appears to be, that the products of a fertilized germ go on accumulating by simple growth, so long as the forces whence growth results are greatly in excess of the antagonist forces; but that when diminution of the one set of forces, or increase of the other, causes a considerable decline in this excess, and an approach towards equilibrium, fertilized germs are again produced. Whether the germ-product be organized round one axis, or round the many axes that arise by agamogenesis—whether the development be continuous or discontinuous; matters not. Whether, as in concrete organisms like the higher animals, this approach to equilibrium results from that disproportionate increase of expenditure entailed by increase of size; or whether, as in

only in individuals that are approaching towards a state of organic equilibrium; and seeing, on the other hand, as we do, that the sperm-cells and germ-cells thrown off by such individuals, are cells in which developmental changes have ended in quiescence, but in which, after their union, there arises a process of active cell-formation; we may suspect that the approach towards a state of general equilibrium in such gamogenetic individuals, is accompanied by an approach towards molecular equilibrium in them; and that the need for this union of sperm-cell and germ-cell, is the need for overthrowing this equilibrium, and re-establishing active molecular change in the detached germ—a result which is probably effected by mixing the slightly different physiological units of slightly different individuals. The several arguments that may be brought in support of this view, cannot be satisfactorily set forth until after the topics of Heredity and Variation have been dealt with. Leaving it for the present, I propose hereafter to reconsider this question, in connexion with sundry others that are raised by the phenomena of Genesis.

Before ending the chapter, however, it may be well to note the relations between these different modes of multiplication, and the conditions of existence under which they are respectively habitual. While the explanation of the teleologist is untrue, it is often an obverse to the truth; for though, on the hypothesis of Evolution, it is clear that things are not arranged thus or thus for the securing of special ends, it is also clear, that arrangements which *do* secure these special ends, tend continually to establish themselves—are established by their fulfilment of these ends. Besides insuring a structural fitness between each kind of organism and its circumstances, the working of "natural selection" also insures a fitness between the mode and rate of multiplication of each kind of organism and its circumstances. We may, therefore, without any teleological implication, consider the fitness of homogenesis and heterogenesis to the needs of the different classes of organisms which exhibit them.

One of the facts to be observed, is, that heterogenesis prevails among organisms of which the food, though abundant compared with their expenditure, is dispersed in such a way that it cannot be appropriated in a wholesale manner. *Protophyta*, subsisting on diffused gases and decaying organic matter in a state of minute subdivision; and *Protozoa*, to which food comes in the shape of extremely small floating particles; are enabled by their rapid agamogenetic multiplication, to obtain materials for growth, better than they would do did they not thus continually divide and disperse in pursuit of it. The higher plants, having for nutriment the carbonic acid of the air and certain mineral components of the soil, show us modes of multiplication adapted to the fullest utilization of these substances. A herb, with but little power of forming the woody-fibre requisite to make a stem that can support wide-spreading branches, after producing a few sexless axes, produces sexual ones; and maintains its race better by the consequent early dispersion of seeds, than by a further production of sexless axes. But a tree, able to lift its successive generations of sexless axes high into the air, where each axis gets carbonic acid and light almost as freely as if it grew by itself, may with advantage go on budding-out sexless axes year after year; since it thereby increases its subsequent power of budding-out sexual axes. Meanwhile, it may advantageously transform into seed-bearers, those axes which, in consequence of their less direct access to materials absorbed by the roots, are failing in their nutrition; for in doing this, it is throwing-off from a point at which sustenance is deficient, a migrating group of germs that may find sustenance elsewhere. The heterogenesis displayed by animals of the Cœlenterate type, has evidently a like utility. A polype, feeding on minute annelids and crustaceans, which, flitting through the water, come in contact with its tentacles;

and limited to that quantity of prey which chance brings within its grasp; buds out young polypes which, either as a colony or as dispersed individuals, spread their tentacles through a larger space of water than the parent alone can; and by producing them, the parent better insures the continuance of its species, than it would do if it went on slowly growing until its nutrition was nearly balanced by its waste, and then multiplied by gamogenesis. Similarly with the *Aphis*. Living on sap sucked through its proboscis from tender shoots and leaves, and able thus to take in but a very small quantity in a given time, this creature's race is more likely to be preserved by a rapid asexual propagation of small individuals, which disperse themselves over a wide but nowhere rich area of nutrition, than it would be did the individual growth continue so as to produce large individuals multiplying sexually. While at the same time we see, that when autumnal cold and diminishing supply of sap, put a check to growth, the recurrence of gamogenesis, and production of fertilized ova that remain dormant through the winter, is more favourable to the preservation of the race, than would be a further continuance of agamogenesis. On the other hand, it is obvious that among the higher animals, living on food which, though dispersed, is more or less aggregated into large masses, this alternation of gamic and agamic reproduction ceases to be useful. The development of the germ-product into a single organism of considerable bulk, is in many cases a condition without which these large masses of nutriment could not be appropriated; and here the formation of many individuals instead of one, would be fatal. But we still see the beneficial results of the general law—the postponement of gamogenesis until the rate of growth begins to decline. For so long as the rate of growth continues rapid, it is a proof that the organism gets food with great facility—that expenditure is not such as seriously to check accumulation; and that the size reached is as yet not disadvantageous—or rather, indeed, that it is advantageous. But

CHAPTER VIII.

HEREDITY.

§ 80. ALREADY, in the last two chapters, the law of hereditary transmission has been tacitly assumed; as, indeed, it unavoidably is in all such discussions. Understood in its entirety, the law is, that each plant or animal produces others of like kind with itself: the likeness of kind consisting, not so much in the repetition of individual traits, as in the assumption of the same general structure. This truth has been rendered so familiar by daily illustration, as almost to have lost its significance. That wheat produces wheat—that existing oxen have descended from ancestral oxen—that every unfolding organism eventually takes the form of the class, order, genus, and species from which it sprang; is a fact which, by force of repetition, has acquired in our minds almost the aspect of a necessity. It is in this, however, that Heredity is principally displayed: the phenomena commonly referred to it, being quite subordinate manifestations. And, as thus understood, Heredity is universal. The various instances of heterogenesis lately contemplated, seem, indeed, to be at variance with this assertion. But they are not really so. Though the recurrence of like forms, is, in these instances, not direct but cyclical, still, the like forms do recur; and when taken together, the group of forms produced during one of the cycles, is as much like the groups produced in preceding cycles, as the single individual arising by homogenesis, is like ancestral individuals.

While, however, the general truth that organisms of a given type uniformly descend from organisms of the same type, is so well established by infinite illustrations, as to have assumed the character of an axiom; it is not universally admitted that non-typical peculiarities are inherited. While the botanist would be so incredulous if told that a plant of one class had produced a plant of another class, or that from seeds belonging to one order individuals belonging to another order had grown, that he would deem it needless to examine the evidence; and while the zoologist would treat with contempt the assertion, that from the egg of a fish a reptile had arisen, or that an implacental mammal had borne a placental mammal, or that an unguiculate quadruped had sprung from an ungulate quadruped, or even that from individuals of one species offspring of an allied species had proceeded; yet there are botanists and zoologists who do not consider it certain, that the minor specialities of organization are transmitted from one generation to another. Some naturalists seem to entertain a vague belief, that the law of Heredity applies only to main characters of structure, and not to details; or, at any rate, that though it applies to such details as constitute differences of species, it does not apply to smaller details. The circumstance that the tendency to repetition, is in a slight degree qualified by the tendency to variation (which, as we shall hereafter see, is but an indirect result of the tendency to repetition), leads some to doubt whether Heredity is unlimited. A careful weighing of the evidence, however, and a due allowance for the influences by which the minuter manifestations of Heredity are obscured will remove the grounds for this scepticism.

First in order of importance, comes the fact, that not only are there uniformly transmitted from an organism to its offspring, those traits of structure which distinguish the class, order, genus, and species; but also those which distinguish the variety. We have numerous cases, among both plants and animals, where, by natural or artificial conditions, there have been produced divergent modifications of the same species; and abundant proof exists that the members of any one sub-species, habitually transmit their distinctive peculiarities to their descendants. Agriculturists and gardeners can furnish unquestionable illustrations. Several varieties of wheat are known; of which each reproduces itself. Since its introduction into England, there have been formed from the potato, a number of sub-species: some of them differing greatly in their forms, sizes, qualities, and periods of ripening. Of peas, also, the like may be said. And the case of the cabbage-tribe, is often cited as showing the permanent establishment of races that have diverged widely from a common stock. Among fruits and flowers, the multiplication of kinds, and the continuance of each kind with certainty by agamogenesis, and to some extent by gamogenesis, might be exemplified without end. From all sides evidence may be gathered showing a like persistence of varieties in each species of animal. We have our distinct breeds of sheep, our distinct breeds of cattle, our distinct breeds of horses: each breed maintaining its characteristics. The several sorts of dogs, which, if we accept the physiological test, we must consider as all of one species, show us in a marked manner the hereditary transmission of small differences—each sort, when kept pure, reproducing itself not only in size, form, colour, and quality of hair, but also in disposition and speciality of intelligence. Rabbits, too, have their permanently-established races. And in the Isle of Man, we have a tail-less kind of cat. Even in the absence of other evidence, that which ethnology furnishes would suffice. Grant them to be derived from one stock, and the varieties of man yield proof upon proof that non-specific traits of structure are bequeathed from generation to generation. Or grant only that there is evidence of their derivation from several stocks, and we still have, between races descended from a common stock, distinctions which prove the inheritance of minor peculiarities. Besides seeing that

verified as to rank with exact science, there are no inductions so trustworthy as those which have undergone the mercantile test. When we have thousands of men whose profit or loss depends on the truth of the inferences they draw from simple and perpetually-repeated observations; and when we find that the inference arrived at, and handed down from generation to generation of these deeply-interested observers, has become an unshakable conviction; we may accept it without hesitation. In breeders of animals we have such a class, led by such experiences, and entertaining such a conviction—the conviction that minor peculiarities of organization are inherited as well as major peculiarities. Hence the immense prices given for successful racers, bulls of superior forms, sheep that have certain desired peculiarities. Hence the careful record of pedigrees of high-bred horses and sporting dogs. Hence the care taken to avoid intermixture with inferior stocks. Citing the highest authorities respecting the effects of breeding from animals having certain superiorities, with the view of propagating those superiorities, Mr Darwin writes:—"Youatt, who was probably better acquainted with the works of agriculturists than almost any other individual, and who was himself a very good judge of an animal, speaks of the principle of selection as 'that which enables the agriculturist not only to modify the character of his flock, but to change it altogether. It is the magician's wand, by means of which he may summon into life whatever form and mould he pleases.'" Lord Somerville, speaking of what breeders have done for sheep, says:—"It would seem that they had chalked upon a wall a form perfect in itself and then given it existence." That most skilful breeder, Sir John Sebright, used to say, with respect to pigeons, that "he would produce any given feather in three years, but it would take him six years to obtain head and beak." In all which statements the tacit assertion is, that individual traits are bequeathed from generation to generation; and that when they are not brought into conflict with opposite traits, they may be so perpetuated and increased as to become permanent distinctions.

Of special instances, there are many besides that of the often-cited Otter-breed of sheep, descended from a single short legged lamb, and that of the six-fingered Grutio Kelleia, who transmitted his peculiarity in different degrees, to several of his children and to some of his grandchildren. In a paper contributed to the *Edinburgh New Philosophical Journal* for July 1863, Dr Struthers gives several cases of hereditary digital variations. Esther P—, who had six fingers on one hand, bequeathed this malformation, along some lines of her descendants, for two, three, and four generations. A— S— inherited an extra digit on each hand and each foot from his father; and C— G—, who also had six fingers and six toes, had an aunt and a grandmother similarly formed. A collection of evidence has been made by Mr Sedgwick, and published by him in the *Medico-Chirurgical Review* for April and for July 1863, in two articles on "The Influence of Sex in limiting Hereditary Transmission." From these articles are selected the following cases and authorities:—Augustin Duforet, a pastry-cook of Douai, who had but two instead of three phalanges to all his fingers and toes, inherited this malformation from his grandfather and father, and had it in common with an uncle and numerous cousins. An account has been given by Dr Lepine, of a man with only three fingers on each hand and four toes on each foot, and whose grandfather and son exhibited the like anomaly. Béchet describes Victoire Barré as a woman who, like her father and sister, had but one developed finger on each hand, and but two toes on each foot, and whose monstrosity re-appeared in two daughters. And there is a case where the absence of two distal phalanges on the hands was traced for two generations. The various recorded instances in which there has been transmission from one generation to another, of webbed-fingers, of webbed-toes, of hare-lip, of congenital luxation of the thigh, of absent patellæ, of club-foot, &c., would occupy more space than can here be spared. Defects in the organs of sense are also not unfrequently inherited. Four sisters, their mother, and grandmother, are described by Duval as similarly affected by cataract. Prosper Lucas details an example of hereditary amaurosis affecting the females of a family for three generations. Duval, Graffe, Dufon, and others testify to like cases coming under their observation.* Deafness, too, is occasionally transmitted from parent to child. There are deaf-mutes whose imperfections have been derived from ancestors; and malformations of the external ears have also been perpetuated in offspring. Of transmitted peculiarities of the skin and its appendages, many illustrations have been noted. One is that of a family remarkable for enormous black eyebrows; another that of a family in which every member had a lock of hair of a lighter colour than the rest on the top of the head; and there are also instances of congenital baldness being hereditary. Entire absence of teeth, absence of particular teeth, and anomalous arrangements of teeth, are recorded as traits that have descended to children. And we have evidence that soundness and unsoundness of teeth are transmissible.

The inheritance of such diseases as gout, consumption, and insanity, is universally admitted. Among the less-common diseases of which the descent from one generation to another has been observed, are, ichthyosis, leprosy, pityriasis, sebaceous tumours, plica polonica, dipsomania, somnambulism, catalepsy, epilepsy, asthma, apoplexy, elephantiasis. General nervousness displayed by parents, almost always re-appears in their children. Even a bias towards suicide appears to be sometimes hereditary.

§ 82. To prove the transmission of those structural peculiarities that have resulted from functional peculiarities, is,

* While this chapter is passing through the press, I learn from Mr White Cooper, that not only are near sight, long sight, dull sight, and squinting, hereditary; but that a peculiarity of vision confined to one eye, is frequently transmitted—re-appearing in the same eye in offspring.

they cannot be classed as "spontaneous variations." They are modifications of structure, consequent on modifications of function, that have been produced by modifications in the actions of external forces. And as these modifications re-appear in succeeding generations, we have, in them, examples of functionally-established variations that are hereditarily transmitted. Further evidence is supplied by what are called "sports" in plants. These are of two kinds—the gamogenetic and the agamogenetic. The gamogenetic may be ascribed wholly to "spontaneous variations;" or if they are partly due to the inheritance of structural changes that are produced by functional changes, this cannot be proved. But where the individuals displaying the variations arise by agamogenesis, the reverse is the case: spontaneous variation is out of the question; and the only possible interpretation is deviation of structure caused by deviation of function. A new axis which buds out from a parent-axis, assumes an unlike character—gives off lobed leaves in place of single leaves, or has an otherwise different mode of growth. This change of structure implies change in the developmental actions which produced the new bud—change, that is, in the actions going on in the parent shoot—functional change. And since the modified structure thus impressed on the new shoot by modified function, is transmitted by it to all the shoots it bears; we are obliged to regard the case as one of acquired modification that has become hereditary.

Evidence of analogous changes in animals, is difficult to disentangle. Only among domesticated animals, have we any opportunity of tracing the effects of altered habits; and here, in nearly all cases, artificial selection has obscured the results. Still, there are some facts which seem to the point. Mr Darwin, while ascribing almost wholly to "natural selection" the production of those modifications which eventuate in differences of species, nevertheless admits the effects of use and disuse. He says—"I find in the domestic duck that the bones of the wing weigh less and the bones of the leg more, in proportion to the whole skeleton, than do the same bones in the wild duck; and I presume that this change may be safely attributed to the domestic duck flying much less, and walking more, than its wild parent. The great and inherited development of the udders in cows and goats in countries where they are habitually milked, in comparison with the state of these organs in other countries, is another instance of the effect of use. Not a single domestic animal can be named which has not in some country drooping ears; and the view suggested by some authors, that the drooping is due to the disuse of the muscles of the ear, from the animals not being much alarmed by danger, seems probable." Again—"The eyes of moles and of some burrowing rodents are rudimentary in size, and in some cases are quite covered up by skin and fur. This state of the eyes is probably due to gradual reduction from disuse, but aided perhaps by natural selection." * * * "It is well known that several animals, belonging to the most different classes, which inhabit the caves of Styria and of Kentucky, are blind. In some of the crabs the footstalk of the eye remains, though the eye is gone; the stand for the telescope is there, though the telescope with its glasses has been lost. As it is difficult to imagine that eyes, though useless, could be in any way injurious to animals living in darkness, I attribute their loss wholly to disuse." The direct inheritance of an acquired peculiarity is sometimes observable. Mr Lewes gives a case. He "had a puppy taken from its mother at six weeks old, who, although never taught, 'to beg' (an accomplishment his mother had been taught), spontaneously took to begging for everything he wanted when about seven or eight months old: he would beg for food, beg to be let out of the room, and one day was found opposite a rabbit hutch begging for rabbits." Instances are on record, too, of sporting dogs which spontaneously adopted in the field, certain modes of behaviour which their parents had learnt.

But the best examples of inherited modifications produced by modifications of function, occur in the human race. To no other cause can be ascribed the rapid metamorphoses undergone by the British races when placed in new conditions. It is notorious that, in the United States, the descendants of the immigrant Irish lose their Celtic aspect, and become Americanized. This cannot be ascribed to intermarriage with Americans; since the feeling with which Irish are regarded by Americans, prevents any considerable amount of intermarriage. Equally marked is the case of the immigrant Germans, who, though they keep themselves very much apart, rapidly assume the prevailing type. To say that "spontaneous variation" increased by natural selection, can have produced this effect, is going too far. Races so numerous, cannot have been supplanted in the course of two or three generations by varieties springing from them. Hence there is no escape from the conclusion, that physical and social conditions have here wrought modifications of function and structure, which offspring have inherited and increased. Similarly with special cases. In the *Cyclopædia of Practical Medicine*, Vol. II. p. 419, Dr Brown states that he "has in many instances observed in the case of individuals whose complexion and general appearance has been modified by residence in hot climates, that children born to them subsequently to such residence, have resembled them rather in their acquired than primary mien."

Some special modifications of organs caused by special changes in their functions, may also be noted. That large hands are inherited by men and women whose ancestors led laborious lives; and that men and women whose descent, for many generations, has been from those unused to manual labour, commonly have small hands; are established opinions. It seems very unlikely that in the absence of any such connexion, the size of the hand should thus have come to be generally regarded as some index of extraction. That there exists a like relation between habitual use of the feet and largeness of the feet, we have strong evidence in the customs of the Chinese. The torturing practice of artificially arresting the

combination of such cadences, more or less idealized, which constitutes melody, has all along had a meaning in the average mind, only because of the meaning which cadences had acquired in the average mind; and that by the continual hearing and practice of melody, there has been gained and transmitted an increasing musical sensibility. Confirmation of this view may be drawn from individual cases. Grant that among a people endowed with musical faculty to a certain degree, spontaneous variation will occasionally produce men possessing it in a higher degree; it cannot be granted that spontaneous variation accounts for the frequent production, by such highly-endowed men, of men still more highly endowed. On the average, the offspring of marriage with others not similarly endowed, will be less distinguished rather than more distinguished. The most that can be expected is, that this unusual amount of faculty shall re-appear in the next generation undiminished. How then shall we explain cases like those of Bach, Mozart, and Beethoven, who were all sons of men having unusual musical powers, but who greatly excelled their fathers in their musical powers? What shall we say to the facts, that Haydn was the son of the organist, that Hummel was born to a music master, and that Weber's father was a distinguished violinist? The occurrence of so many cases in one nation, within a short period of time, cannot rationally be ascribed to the coincidence of "spontaneous variations." It can be ascribed to nothing but inherited developments of structure, caused by augmentations of function.

But the clearest proof that structural alterations caused by alterations of function, are inherited, occurs when the alterations are morbid. "Certain modes of living engender gout;" and gout is transmissible. It is well known that in persons previously healthy, consumption may be produced by unfavourable conditions of life—by bad and insufficient food; by foul, damp, unventilated habitations; and even by long-continued anxiety. It is still more notorious that the consumptive diathesis is conveyed from parent to child. Unless, then, a distinction be assumed between constitutional consumption and consumption induced by unwholesome conditions—unless it be asserted that consumption of unknown origin is transmissible, while functionally-produced consumption is not; it must be admitted that those changes of structure from which the consumptive diathesis results, may be caused in parents by changes of function, and may be inherited by their children. Most striking of all, however, is the fact lately brought to light, that functional disorders artificially established, may be conveyed to offspring. Some few years since M. Brown-Sequard, in the course of inquiries into the nature and causes of epilepsy, hit on a method by which epilepsy could be originated. Guinea-pigs were the creatures on which, chiefly, he experimented; and eventually, he discovered the remarkable fact, that the young of these epileptic guinea-pigs were epileptic: the functionally-established epilepsy in the parents, became constitutional epilepsy in the offspring. Here we have an instance which, standing even alone, decides the question. We have a special form of nervous action, not caused by any natural variation of structure that had arisen spontaneously in the organism, but one caused by a certain incidence of external forces. We have this special form of nervous action becoming confirmed by repetition: the fits are more and more easily induced—there is established the epileptic *habit*. That is to say, the connected nervous actions constituting a fit, produce in the nervous system such changes of structure, that subsequent connected nervous actions of like kind, follow one another with increased readiness. And that this epileptic habit is inherited, proves conclusively that these structural modifications worked by functional modifications, are impressed on the whole organism in such way as to affect the reproductive centres, and cause them to unfold into organisms that exhibit like modifications.

Evidence nearly allied to this, and scarcely less significant, is furnished by that transmission of general nervousness, noticed in the last section. Nervousness is especially common among classes of people who tax their brains much. Among these classes, we daily see this constitutional modification *produced* by excess of function, in men whose progenitors were not nervous; and the children of such men habitually inherit more or less of the modification.

§ 83. Two modified manifestations of Heredity remain to be noticed. The one is the re-appearance in offspring, of traits not borne by the parents, but borne by the grandparents or by remoter ancestors. The other is the limitation of Heredity by sex—the restriction of certain transmitted peculiarities to offspring of the same sex as the parent possessing these peculiarities.

Atavism, which is the name given to the recurrence of ancestral traits, is proved by many and varied facts. In the picture-galleries of old families, and on the monumental brasses in the adjacent churches, are often seen types of feature that are still, from time to time, repeated in members of these families. It is matter of common remark that some constitutional diseases, such as gout and insanity, after missing a generation, will show themselves in the next. Dr Struthers, in his above-quoted paper on "Variation in the Number of Fingers and Toes, and of the Phalanges, in Man," gives cases of malformations that were common to grandparent and grandchild, but of which the parent had no trace. M. Girou (as quoted by Mr Sedgwick) says—"One is often surprised to see lambs black, or spotted with black, born of ewes and rams with white wool, but if one takes the trouble to go back to the origin of this phenomenon, it is found in the ancestors." Instances still more remarkable, in which the remoteness of the ancestors copied is very great, are given by Mr Darwin. He points out that in crosses between varieties of the pigeon, there will sometimes re-appear the plumage of the original rock-pigeon, from which these varieties descended; and he instances the faint zebra-like markings occasionally traceable in horses, as having probably a like meaning.

and for accepting the opposite supposition, that they are cells differing from others rather in being unspecialized. And here the assumption to which we seem driven by the *ensemble* of the evidence, is, that sperm-cells and germ-cells are essentially nothing more than vehicles, in which are contained small groups of the physiological units in a fit state for obeying their proclivity towards the structural arrangement of the species they belong to.

Thus the phenomena of Heredity are seen to assimilate with other phenomena; and the assumption which these other phenomena thrust on us, appears to be equally thrust on us by the phenomena of Heredity. We must conclude that the likeness of any organism to either parent, is conveyed by the special tendencies of the physiological units derived from that parent. In the fertilized germ we have two groups of physiological units, slightly different in their structures. These slightly-different units, severally multiply at the expense of the nutriment supplied to the unfolding germ —each kind moulding this nutriment into units of its own type. Throughout the process of evolution, the two kinds of units, mainly agreeing in their polarities and in the form which they tend to build themselves into, but having minor differences, work in unison to produce an organism of the species from which they were derived, but work in antagonism to produce copies of their respective parent-organisms. And hence ultimately results, an organism in which traits of the one are mixed with traits of the other.

If the likeness of offspring to parents is thus determined, it becomes manifest, *à priori*, that besides the transmission of generic and specific peculiarities, there will be a transmission of those individual peculiarities which, arising without assignable causes, are classed as "spontaneous." For if the assumption of a special arrangement of parts by an organism, is due to the proclivity of its physiological units towards that arrangement; then the assumption of an arrangement of parts slightly different from that of the species, implies physiological units slightly unlike those of the species; and these slightly-unlike physiological units, communicated through the medium of sperm-cell or germ-cell, will tend, in the offspring, to build themselves into a structure similarly diverging from the average of the species.

It is not equally manifest, *à priori*, however, that on this hypothesis, alterations of structure caused by alterations of function, must be transmitted to offspring. It is not obvious that change in the form of a part, caused by changed action, involves such change in the physiological units throughout the organism, that these, when groups of them are thrown off in the shape of reproductive centres, will unfold into organisms that have this part similarly changed in form. Indeed, when treating of Adaptation (§ 69), we saw that an organ modified by increase or decrease of function, can but slowly so re-act on the system at large, as to bring about those correlative changes required to produce a new equilibrium; and yet only when such new equilibrium has been established, can we expect it to be *fully* expressed in the modified physiological units of which the organism is built—only then can we count on a complete transfer of the modification to descendants. Nevertheless, that changes of structure caused by changes of action, must also be transmitted, however obscurely, from one generation to another, appears to be a deduction from first principles—or if not a specific deduction, still, a general implication. For if an organism A, has, by any peculiar habit or condition of life, been modified into the form A′, it follows inevitably, that all the functions of A′, reproductive function included, must be in some degree different from the functions of A. An organism being a combination of rhythmically-acting parts in moving equilibrium, it is impossible to alter the action and structure of any one part, without causing alterations of action and structure in all the rest; just as no member of the Solar System could be modified in motion or mass, without producing re-arrangements throughout the whole Solar System. And if the organism A when changed to A′, must be changed in all its functions: then the offspring of A′ cannot be the same as they would have been had it retained the form A. It involves a denial of the persistence of force to say that A may be changed into A′, and may yet beget offspring exactly like those it would have begotten had it not been so changed. That the change in the offspring must, other things equal, be in the same direction as the change in the parent, we may dimly see is implied by the fact, that the change propagated throughout the parental system is a change towards a new state of equilibrium—a change tending to bring the actions of all organs, reproductive included, into harmony with these new actions. Or, bringing the question to its ultimate and simplest form, we may say that as, on the one hand, physiological units will, because of their special polarities, build themselves into an organism of a special structure; so, on the other hand, if the structure of this organism is modified by modified function, it will impress some corresponding modification on the structures and polarities of its units. The units and the aggregate must act and re-act on each other. The forces exercised by each unit on the aggregate and by the aggregate on each unit, must ever tend towards a balance. If nothing prevents, the units will mould the aggregate into a form in equilibrium with their pre-existing polarities. If, contrariwise, the aggregate is made by incident actions to take a new form, its forces must tend to re-mould the units into harmony with this new form. And to say that the physiological units are in any degree so re-moulded as to bring their polar forces towards equilibrium with the forces of the modified aggregate, is to say that when separated in the shape of reproductive centres, these units will tend to build themselves up into an aggregate modified in the same direction.

have lost their horns. At one time, there existed in Scotland a race of pigs with solid feet instead of cleft feet. In pigeons, according to Mr Darwin, "the number of the caudal and sacral vertebræ vary; as does the number of the ribs, together with their relative breadth and the presence of processes."

That variations both small and large which arise without any specific assignable cause, tend to become hereditary, was shown in the last chapter. Indeed the evidence which proves Heredity in its smaller manifestations, is the same evidence which proves Variation; since it is only when there occur variations, that the inheritance of anything beyond the structural peculiarities of the species, can be proved. It remains here, however, to be observed, that the transmission of variations is itself variable; and that it varies both in the direction of decrease and in the direction of increase. An individual trait of one parent, may be so counteracted by the influence of the other parent, that it may not appear in the offspring; or not being so counteracted, the offspring may possess it, perhaps in an equal degree or perhaps in a less degree; or the offspring may exhibit the trait in even a still higher degree. Of the illustrations of this, one must suffice. I quote it from the essay by Dr Struthers, referred to in the last chapter.

"The great-great-grandmother, Esther P—— (who married A—— L——), had a sixth little finger on one hand. Of their eighteen children (twelve daughters and six sons), only one (Charles) is known to have had digital variety. We have the history of the descendants of three of the sons, Andrew, Charles, and James.

"(1.) Andrew L—— had two sons, Thomas and Andrew; and Thomas had two sons all without digital variety. Here we have three successive generations without the variety possessed by the great-grandmother showing itself.

"(2.) James L——, who was normal, had two sons and seven daughters, also normal. One of the daughters became Mrs J—— (one of the informants), and had three daughters and five sons, all normal except one of the sons, James J——, now æt. 17, who had six fingers on each hand. * * *

"In this branch of the descendants of Esther, we see it passing over two generations and reappearing in one member of the third generation, and now on both hands.

"(3.) Charles L——, the only child of Esther who had digital variety, had six fingers on each hand. He had three sons, James, Thomas, and John, all of whom were born with six fingers on each hand, while John has also a sixth toe on one foot. He had also five other sons and four daughters, all of whom were normal.

"(*a.*) Of the normal children of this, the third generation, the five sons had twelve sons and twelve daughters, and the four daughters have had four sons and four daughters, being the fourth generation, all of whom were normal. A fifth generation in this sub-group consists as yet of only two boys and two girls, who are also normal.

"In this sub-branch, we see the variety of the first generation present in the second, passing over the third and fourth, and also the fifth as far as it has yet gone.

"(*b.*) James had three sons and two daughters, who are normal.

"(*c.*) Thomas had four sons and five daughters, who are normal; and has two grandsons, also normal.

"In this sub-branch of the descent, we see the variety of the first generation, showing itself in the second and third, and passing over the fourth, and (as far as it yet exists) the fifth generation.

"(*d.*) John L —— (one of the informants) had six fingers, the additional finger being attached on the outer side, as in the case of his brothers James and Thomas. All of them had the additional digits removed. John has also a sixth toe on one foot, situated on the outer side. The fifth and sixth toes have a common proximal phalanx, and a common integument invests the middle and distal phalanges, each having a separate nail.

"John L—— has a son who is normal, and a daughter Jane, who was born with six fingers on each hand and six toes on each foot. The sixth fingers were removed. The sixth toes are not wrapped with the fifth as in her father's case, but are distinct from them. The son has a son and daughter, who, like himself, are normal.

"In this, the most interesting sub-branch of the descent, we see digital increase, which appeared in the first generation on one limb, appearing in the second on two limbs, the hands; in the third on three limbs, the hands and one foot; in the fourth on all the four limbs. There is as yet no fifth generation in uninterrupted transmission of the variety. The variety does not yet occur in any number of the fifth generation of Esther's descendants, which consists, as yet, only of three boys and one girl, whose parents were normal, and of two boys and two girls, whose grandparents were normal. It is not known whether in the case of the great-great-grandmother, Esther P——, the variety was original or inherited."*

§ 86. Where there is great uniformity among the members of a species, the divergences of offspring from the average type, are usually small; but where, among the members of a species, considerable unlikenesses have once been established, unlikenesses among the offspring are frequent and great. Wild plants growing in their natural habitats, are uniform over large areas, and maintain from generation to generation like structures; but when cultivation has caused appreciable differences among the members of any species of plant, extensive and numerous deviations are apt to arise. Similarly, between wild and domesticated

* This remarkable case appears to militate against the conclusion, drawn some few pages back, that the increase of a peculiarity by coincidence of "spontaneous variations" in successive generations, is very improbable; and that the special superiorities of musical composers cannot have thus arisen. The reply is, that the extreme frequency of the occurrence among so narrow a class as that of musical composers, forbids the interpretation thus suggested.

their feet, while in others, there was present on each hind-foot what is called the "dew-claw"—a rudimentary fifth digit.

Thus, induction points to three causes of variation, all in action together. We have heterogeneity among progenitors, which, did it act uniformly and alone in generating, by composition of forces, new deviations, would impress such new deviations to the same extent on all offspring of the same parents; which it does not. We have functional variation in the parents, which, acting either alone or in combination with the preceding cause, would entail like variations on all young ones simultaneously produced; which it does not. And there is consequently some third cause of variation, yet to be found, which acts along with the structural and functional variations of ancestors and parents.

§ 87 Already, in the last section, there has been implied some relation between variation and the action of external conditions. The above-cited contrast, between the uniformity of wild species and the multiformity of the same species when cultivated or domesticated, thrusts this truth upon us. Respecting the variations of plants, Mr Darwin remarks that "'sports' are extremely rare under nature, but far from rare under cultivation." Others who have studied the matter assert, that if a species of plant which, up to a certain time, has maintained great uniformity, once has its constitution thoroughly disturbed, it will go on varying indefinitely. Though, in consequence of the remoteness of the periods at which they were domesticated, there is a lack of positive proof that our extremely variable domestic animals have become variable under the changed conditions implied by domestication, having been previously constant; yet competent judges do not doubt that this has been the case.

Now the constitutional disturbance which precedes variation, can be nothing else than an overthrowing of the pre-established equilibrium of functions. Transferring a plant from forest lands to a ploughed field or a manured garden, is altering the balance of forces to which it has been hitherto subject; by supplying it with different proportions of the assimilable matters it requires, and taking away some of the positive impediments to its growth which competing wild plants before offered. An animal taken from woods or plains, where it lived on wild food of its own procuring, and placed under restraint, while artificially supplied with food not quite like what it had before, is an animal subject to new outer actions, to which its inner actions must be re-adjusted. From the general law of equilibration we found it to follow, that "the maintenance of such a moving equilibrium" as an organism displays, "requires the habitual genesis of internal forces corresponding in number, directions, and amounts, to the external incident forces — as many inner functions, single or combined, as there are single or combined outer actions to be met" (*First Principles*, § 133); and more recently (§ 27), we have seen that Life itself is "the definite combination of heterogeneous changes, both simultaneous and successive, in correspondence with external co-existences and sequences." Necessarily, therefore, an organism exposed to a permanent change in the arrangement of outer forces, must undergo a permanent change in the arrangement of inner forces. The old equilibrium must be destroyed; and a new equilibrium must be established. There must be functional perturbations, ending in a re-adjusted balance of functions.

If, then, change of conditions is the only known cause by which the original homogeneity of a species is destroyed; and if change of conditions can affect an organism only by altering its functions; it follows that alteration of functions is the only known internal cause to which the commencement of variation can be ascribed. That such minor functional changes as parents undergo from year to year, are influential on the offspring, we have seen to be proved by the greater unlikeness that exists between children born to the same parents at different times, than exists between twins. And here we seem forced to conclude, that the larger functional variations produced by greater external changes, are the initiators of those structural variations which, when once commenced in a species, lead by their combinations and antagonisms to multiform results. Whether they are or are not the direct initiators, they must still be the indirect initiators.

§ 88. That they are not in all cases, or even in most cases, the direct initiators, is clear. Were they so, those unlikenesses which exist between plants that grow from seeds out of the same seed-vessel, or between animals belonging to the same litter, would be inexplicable. Here, all the antecedents, structural and functional, appear to be alike for each of the new organisms. Any deviations caused by structural contrasts or functional disturbances in the parents, must be equally shared in by all simultaneously-produced offspring. Hence, an explanation of the variations arising under such conditions, has still to be sought.

These are the variations termed "spontaneous." Not that those who apply to them this word or some equivalent, mean to imply that they are uncaused. Mr Darwin expressly guards himself against such an interpretation. He says:— "I have hitherto sometimes spoken as if the variations—so common and multiform in organic beings under domestication, and in a lesser degree in those in a state of nature—had been due to chance. This, of course, is a wholly incorrect expression, but it serves to acknowledge plainly our ignorance of the cause of each particular variation." Not only, however, do I hold, in common with Mr Darwin, that there must be some cause for these apparently-spontaneous variations; but it seems to me that a definite cause is assignable. I think it may be shown that unlikenesses must necessarily arise between the new individuals simultaneously produced by the same parents. Instead of the occurrence of such

respect to incident forces; and that being subject to forces that are more or less unlike, they must become more or less unlike. Hence, no two ova in an ovarum or ovules in a seed-vessel—no two spermatozoa or pollen-cells, can be identical. Whether or not there arise other contrasts, there are certain to arise quantitative contrasts; since the process of nutrition cannot be absolutely alike for all. The reproductive centres must begin to differentiate from the very outset. Such being the necessities of the case, what will happen on any successive or simultaneous fertilizations? There will inevitably result more or less unlikeness between the combined parental influences in every instance. Quantitative differences among the sperm-cells and among the germ-cells, will insure this. Grant that the number of physiological units contained in any one reproductive cell, can rarely if ever be exactly equal to the number contained in any other, ripened at the same time or at a different time; and it follows that among the fertilized germs produced by the same parents, the physiological units derived from each parent will bear a different numerical ratio to each other in every case. If now the parents are constitutionally alike, that is, alike in the polarities of their physiological units, the variation in the ratio between the physiological units they severally bequeath to the fertilized germs, cannot cause unlikenesses among the offspring. But if otherwise, no two of the offspring can be alike. In every case, the small initial difference in the proportions of the slightly-unlike units, will lead, during evolution, to a continual multiplication of differences: the insensible divergence at the outset, will generate sensible divergences at the conclusion. Possibly some may hence infer, that though, in such case, the offspring must differ somewhat from each other and from both parents; yet that in every one of them there must result a homogeneous mixture of the traits of the two parents. A little consideration shows that the reverse is inferable. If, throughout the process of development, the physiological units derived from each parent, preserved the same ratio to each other in all parts of the growing organism, each organ would show as much as every other, the influence of either parent. But we know, *à priori*, that no such uniform distribution is possible. It has been shown (*First Principles*, § 123), that in any mixed aggregate of units, segregation must inevitably go on. Incident forces will tend ever to cause separation of the two orders of units from each other—will integrate groups of the one order in one place, and groups of the other order in another place. Hence there must arise, not a homogeneous mean between the two parents; but a mixture of organs, some of which mainly follow the one parent and some the other. And this is the kind of mixture which observation shows us.

Still it may be fairly objected, that however the attributes of the two parents are variously mixed in their several offspring, they must in all the offspring fall between the extremes displayed in the parents. In no characteristic could one of the young exceed both parents, were there no cause of "spontaneous variation" but the one alleged. Evidently, then, there is a cause yet unfound.

§ 89. Thus far we have contemplated the process under its simplest aspect. While we have assumed the two parents to be somewhat unlike, we have assumed that each parent has a homogeneous constitution—is built up of physiological units that are exactly alike. But in no case can such a homogeneity exist. Each parent had parents that were more or less contrasted—each parent inherited at least two orders of physiological units, not quite identical. Here then we have a further cause of variation. The sperm-cells or germ-cells which any organism produces, will differ from each other not quantitatively only, but qualitatively. Of the slightly-unlike physiological units bequeathed to an organism, its reproductive cells cannot habitually contain the same proportions; and we may expect the proportions to vary not slightly but greatly. Just as, during the evolution of an organism, the physiological units derived from the two parents tend to segregate, and produce likeness to the male parent in this feature and to the female parent in that; so, during the formation of reproductive cells by such organism, there will arise in one cell a predominance of the physiological units derived from one parent, and in another cell a predominance of the physiological units derived from the other parent. The instability of the homogeneous forbids us to assume an even distribution of the two orders of units in all the reproductive cells. And inequalities once arising among them, must tend ever to become more marked; since, wherever units of a given order have begun to segregate, the process of differentiation and integration tends to segregate them more and more. Thus, then, every fertilised germ, besides containing different *amounts* of the two parental influences, will contain different *kinds* of influences—this having received a marked impress from one maternal or paternal ancestor, and that from another.

Here, then, we have a clue to the multiplied variations, and sometimes extreme variations, that arise in races which have once begun to vary. Amid countless different combinations of units derived from parents, and through them from ancestors, immediate and remote—amid the various conflicts in their slightly-different polarities, opposing and conspiring with each other in all ways and degrees; there will from time to time arise special proportions causing special deviations. From the general law of probabilities it is inferable, that while these involved influences, derived from many progenitors, must, on the average of cases, obscure and partially neutralise one another; there must occasionally result such combinations of them as will produce considerable divergences from average structures; and at rare intervals, such combinations as will produce very marked divergences. There is thus a correspondence between the inferable results, and the results as habitually witnessed.

to affect their constitutions profoundly, and to modify somewhat the physiological units thrown off in their reproductive cells, the divergences produced by these in offspring, will be of diverse kinds. And the original homogeneity of constitution having been thus destroyed, variation may go on with increasing facility. There will result a heterogeneous mixture of modifications of structure, caused by modifications of function; and of still more numerous correlated modifications, indirectly so caused. By natural selection of the most divergent forms, the unlikenesses of parents will grow more marked, and the limits of variation wider. Until at length the divergences of constitutions and modes of life, become great enough to lead to segregation of the varieties.

§ 91. That variations must occur, and that they must ever tend, both directly and indirectly, towards adaptive modifications, are conclusions deducible from first principles; apart from any detailed interpretations like the above. That the state of homogeneity is an unstable state, we have found to be a universal truth. Each species must pass from the uniform into the more or less multiform, unless the incidence of external forces is exactly the same for all its members; which it never can be. Through the process of differentiation and integration, which of necessity brings together, or keeps together, like individuals, and separates unlike ones from them, there must nevertheless be maintained a tolerably uniform species; so long as there continues a tolerably uniform set of conditions in which it may exist. But if the conditions change, either absolutely by some disturbance of the habitat, or relatively by spread of the species into other habitats, then the divergent individuals that result, must be segregated by the divergent sets of conditions into distinct varieties (*First Principles*, § 126). When, instead of contemplating a species in the aggregate, we confine our attention to a single member and its descendants, we see it to be a corollary from the general law of equilibration, that the moving equilibrium constituted by the vital actions in each member of this family, must remain constant so long as the external actions to which they correspond remain constant; and that if the external actions are changed, the disturbed balance of internal changes, if not overthrown, cannot cease undergoing modification until the internal changes are again in equilibrium with the external actions: corresponding structural alterations having arisen.

Or passing from these derivative laws to the ultimate law, we see that Variation is necessitated by the persistence of force. The members of a species inhabiting any area, cannot be subject to like aggregates of forces over the whole of that area. And if, in different parts of the area, different kinds or amounts or combinations of forces act on them, they cannot but become different in themselves and in their progeny. To say otherwise, is to say that differences in the forces will not produce differences in the effects; which is to deny the persistence of force.

Whence it is also manifest, that there can be no variation of structure, but what is directly or indirectly consequent on variation of function. On the one hand, organisms in complete equilibrium with their conditions, cannot be changed except by change in their conditions; since, to assert otherwise, is to assert that there can be an effect without a cause; which is to deny the persistence of force. On the other hand, any change of conditions can affect an organism only by changing the actions going on in it—only by altering its functions. The alterations of functions being necessarily towards a re-establishment of the equilibrium, (for if not, the equilibrium must be destroyed and the life cease, either in the individual or in descendants,) it follows that the structural alterations directly caused, are adaptations; and that the correlated structural alterations indirectly caused, are the concomitants of adaptations. Hence, though, by the intercourse of organisms that have been functionally and structurally modified in different directions, there may result organisms that deviate in compound ways which appear unrelated to external conditions, the deviations of such organisms must still be regarded as indirect results of functional adaptations. We must say that in all cases, adaptive change of function is the primary and ever-acting cause of that change of structure which constitutes variation; and that the variation which appears to be "spontaneous," is derivative and secondary.

still left unanswered the question—*why* does gamogenesis recur? And to this the reply suggested was, that the approach towards general equilibrium in organisms, "is accompanied by an approach towards molecular equilibrium in them; and that the need for this union of sperm-cell and germ-cell, is the need for overthrowing this equilibrium, and re-establishing active molecular change in the detached germ—a result which is probably effected by mixing the slightly-different physiological units of slightly-different individuals." This is the hypothesis which we have now to consider. Let us first look at the evidences which certain inorganic phenomena furnish.

The molecules of any aggregate which have not a balanced arrangement, inevitably tend towards a balanced arrangement. As before mentioned (*First Principles*, § 103) amorphous wrought iron, when subject to continuous jar, begins to arrange itself into crystals—its atoms assume a condition of polar equilibrium. The particles of unannealed glass, which are so unstably arranged that slight disturbing forces make them separate into small groups, take advantage of that greater freedom of movement given by a raised temperature, to adjust themselves into a state of relative rest. During any such re-arrangement, the aggregate exercises a coercive force over its units. Just as in a growing crystal, the atoms successively assimilated from the solution, are made by the already-crystallized atoms to take a certain form, and even to re-complete that form when it is broken; so in any mass of unstably-arranged atoms that passes into a stable arrangement, each atom conforms to the forces exercised on it by all the other atoms. This is a corollary from the general law of equilibration. We saw (*First Principles*, § 130) that every change is towards equilibrium; and that change can never cease until equilibrium is reached. Organisms, above all other aggregates, conspicuously display this progressive equilibration; because their units are of such kinds, and so conditioned, as to admit of easy re-arrangement. Those extremely active changes which go on during the early stages of evolution, imply an immense excess of the molecular forces over those antagonist forces which the aggregate exercises on the molecules. While this excess continues, it is expended in growth, development, and function—expenditure for any of these purposes, being proof that part of the force embodied in molecular tensions, remains unbalanced. Eventually, however, this excess diminishes. Either, as in organisms which do not expend much force, decrease of assimilation leads to its decline; or, as in organisms which expend much force, it is counterbalanced by the rapidly-increasing re-actions of the aggregate (§ 46). The cessation of growth, when followed, as in some organisms, by death, implies the arrival at an equilibrium between the molecular forces, and those forces which the aggregate opposes to them. When, as in other organisms, growth ends in the establishment of a moving equilibrium, there is implied such a decreased preponderance of the molecular forces, as leaves no surplus beyond that which is used up in functions. The declining functional activity, characteristic of advancing life, expresses a further decline in this surplus. And when all vital movements come to an end, the implication is, that the actions of the units on the aggregate and the re-actions of the aggregate on the units, are completely balanced. Hence, while a state of rapid growth indicates such a play of forces among the units of an aggregate, as will produce active re-distribution; the diminution and arrest of growth, shows that the units have fallen into such relative positions that re-distribution is no longer so facile. When, therefore, we see that gamogenesis recurs only when growth is decreasing, or has come to an end, we must say that it recurs only when the organic units are approximating to equilibrium—only when their mutual restraints prevent them from readily changing their arrangements in obedience to incident forces.

That units of like forms can be built up into a more stable aggregate than units of slightly unlike forms, is tolerably manifest, *à priori*. And we have facts which prove that mixing allied but somewhat different units, *does* lead to comparative instability. Most metallic alloys exemplify this truth. Common solder, which is a mixture of lead and tin, melts at a much lower temperature than either lead or tin. The compound of lead, tin, and bismuth, called "fusible metal," becomes fluid at the temperature of boiling water; while the temperatures at which lead, tin, and bismuth become fluid, are, respectively, 612°, 442°, and 497°, F. Still more remarkable is the illustration furnished by potassium and sodium. These metals are very near akin in all respects—in their specific gravities, their atomic weights, their chemical affinities, and the properties of their compounds. That is to say, all the evidences unite to show that their units, though not identical, have a close resemblance. What now happens when they are mixed? Potassium alone melts at 136°, sodium alone melts at 190°, but the alloy of potassium and sodium, is liquid at the ordinary temperature of the air. Observe the meaning of these facts, expressed in general terms. The maintenance of a solid form by any group of units, implies among them an arrangement so stable, that it cannot be overthrown by the incident forces. Whereas the assumption of a liquid form, implies that the incident forces suffice to destroy the arrangement of the units. In the one case, the thermal undulations fail to dislocate the parts; while in the other case, the parts are so dislocated by the thermal undulations, that they fall into total disorder—a disorder admitting of easy re-arrangement into any other order. For the liquid state is a state in which the units become so far free from mutual restraints, that incident forces can change their relative positions very readily. Thus we have reason to conclude, that an aggregate of units which, though in the main similar to each other, have minor differences, must be more unstable than an aggregate of homogeneous units: the one will yield to disturbing forces which the other successfully resists.

brium. Hence, a group of physiological units cast off from it, will not be wholly without a tendency to undergo the structural re-arrangements which we call development; but will have this tendency unduly restrained by partially-balanced polarities. In the second place, undue restraint of the physiological units, while it renders them as wholes less-easily altered in their relative positions by incident forces, thereby also renders them more liable to be individually decomposed by incident forces: the same thermal undulations which, if the physiological units are comparatively free, will aid their re-arrangement by giving them still greater freedom, will, if they are comparatively fixed, begin to change the arrangements of their components—will decompose them. In the third place, their decomposition will be prevented as well as their re-distribution facilitated, by such disturbance of their polarities as we have seen must result from mixing with them the slightly-unlike units of another organism.

And now let us test this hypothesis, by seeing what power it gives us of interpreting established inductions.

§ 93. The majority of plants being hermaphrodites, it has, until quite recently, been supposed that the ovules of each flower are fertilized by pollen from the anthers of the same flower. Mr Darwin, however, has shown that the arrangements are generally such as to prevent this: either the ovules and the pollen are not ripe simultaneously, or obstacles prevent access of the one to the other. At the same time, he has shown that there exist arrangements, often of a remarkable kind, which facilitate the transfer of pollen by insects from the stamens of one flower to the pistil of another. Similarly, it has been found that among the lower animals, hermaphrodism does not usually involve the production of fertile germs, by the union of sperm-cells and germ-cells developed in the same individual; but that the reproductive centres of one individual are united with those of another, to produce fertile germs. Either, as in the *Pyrosoma*, the *Perophora*, and in many higher molluscs, the ova and spermatozoa are matured at different times; or, as in annelids, they are prevented by their relative positions from coming in contact.

Remembering the fact that among the higher classes of organisms, fertilization is always effected by combining the sperm-cell of one individual with the germ-cell of another; and joining with it the fact that among hermaphrodite organisms, the germ-cells developed in any individual, are usually not fertilized by sperm-cells developed in the same individual; we see reason for thinking that the essential thing in fertilization, is the union of specially-fitted portions of *different* organisms. If fertilization depended on the peculiar properties of sperm-cell and germ-cell, as such; then, in hermaphrodite organisms, it would be a matter of indifference whether the united sperm-cells and germ-cells were those of the same individual, or those of different individuals. But the circumstance that there exist in such organisms, elaborate appliances for mutual fertilization, shows that unlikeness of derivation in the united reproductive centres, is the desideratum. Now this is just what the foregoing hypothesis implies. If, as was concluded, fertilization has for its object the disturbance of that approximate equilibrium existing among the physiological units separated from an adult organism; and if, as we saw reason to think, this object is effected by mixture with the slightly-different physiological units of another organism; then, we at the same time see reason to think, that this object will not be effected by mixture with physiological units belonging to the same organism. Thus, the hypothesis leads us to expect such provisions as we find exist.

§ 94. But here a difficulty presents itself. These propositions seem to involve the conclusion, that self-fertilization is impossible. It apparently follows from them, that a group of physiological units from one part of an organism, ought to have no power of altering the state of approaching balance in a group from another part of it. Yet self-fertilization does occur. Though the ovules of one plant, are generally fertilized by pollen from another plant of the same kind; yet they may be, some of them, fertilized by the pollen of the same plant. And though, among hermaphrodite animals, self-fertilization is usually negatived by structural or functional arrangements; yet in certain *Entozoa*, there appear to be special provisions by which the sperm-cells and germ-cells of the same individual may be united, when not previously united with those of another individual. Certainly, at first sight, these facts do not consist with the above supposition. Nevertheless, there is a satisfactory solution of them.

In the last chapter, when considering the variations that may result in offspring from the combination of unlike parental constitutions, it was pointed out that in an unfolding organism, composed of slightly-different physiological units derived from slightly-different parents, there cannot be maintained an even distribution of the two orders of units. We saw that the instability of the homogeneous, negatives the uniform blending of them; and that, by the process of differentiation and integration, they must be more or less separated; so that in one part of the body the influence of one parent will predominate, and in another part of the body the influence of the other parent: an inference which harmonizes with daily observation. And we also saw, that the sperm-cells or germ-cells produced by such an organism, must, in virtue of these same laws, be more or less unlike one another. It was shown that through segregation, some of the sperm-cells or germ-cells will get an excess of the physiological units derived from one side, and some of them an excess of those derived from the other side: a cause which accounts for the unlikenesses among offspring simultaneously produced. Now from this segregation of the different orders of physiological units, inherited from different parents and lines of ancestry, there arises the possibility of self-fertilization in hermaphrodite organisms. If the physiological units contained in the sperm-

based wholly on observed facts, is just the conclusion to which the foregoing argument points. That necessary action and the re-action between the parts of an organism and the organism as a whole—that power of the aggregate to re-mould the units, which is the correlative of the power of the units to build up into such an aggregate; implies that any differences existing between the units inherited by an organism, must gradually diminish. Being subject in common to the total forces of the organism, they will in common be modified towards congruity with these forces; and therefore towards likeness with each other. If, then, in a self-fertilising organism and its self-fertilizing descendants, such contrasts as originally existed among the physiological units, are progressively obliterated — if, consequently, there can no longer be a segregation of different physiological units in different sperm-cells and germ-cells; self-fertilization will become impossible: step by step the fertility will diminish, and the series will finally die out.

And now observe, in confirmation of this view, that self-fertilization is limited to organisms in which an approximate equilibrium among the organic forces, is not long maintained. While growth is actively going on, and the physiological units are subject to a continually-changing distribution of forces, no decided assimilation of the units can be expected: like forces acting on the unlike units, will tend to segregate them, so long as continuance of evolution permits further segregation; and only when further segregation cannot go on, will the like forces tend to assimilate the units. Hence, where there is no prolonged maintenance of an approximate organic balance, self-fertilization may be possible for some generations; but it will be impossible in organisms distinguished by a sustained moving equilibrium.

§ 95. The interpretation which it affords of sundry phenomena familiar to breeders of animals, adds probability to the hypothesis. Mr Darwin has collected a large "body of facts, showing, in accordance with the almost universal belief of breeders, that with animals and plants a cross between different varieties, or between individuals of the same variety but of another strain, gives vigour and fertility to the offspring; and on the other hand, that *close* interbreeding diminishes vigour and fertility,"—a conclusion harmonizing with the current belief respecting family-intermarriages in the human race. Have we not here a solution of these facts? Relations must, on the average of cases, be individuals whose physiological units are more nearly alike than usual. Animals of different varieties must be those whose physiological units are more unlike than usual. In the one case, the unlikeness of the units may frequently be insufficient to produce fertilization; or, if sufficient to produce fertilization, not sufficient to produce that active molecular change required for vigorous development. In the other case, both fertilization and vigorous development will be made probable.

Nor are we without a cause for the irregular manifestation of these general tendencies. The mixed physiological units composing any organism, being, as we have seen, more or less segregated in the reproductive centres it throws off; there may arise various results, according to the degrees of difference among the units, and the degrees in which the units are segregated. Of two cousins who have married, the common grandparents may have had either similar or dissimilar constitutions; and if their constitutions were dissimilar, the probability that their married grandchildren will have offspring will be greater than if their constitutions were similar. Or the brothers and sisters from whom these cousins descended, instead of severally inheriting the constitutions of their parents in tolerably equal degrees, may have severally inherited them in very different degrees: in which last case, intermarriages among the grandchildren will be less likely to prove infertile. Or the brothers and sisters from whom these cousins descended, may severally have married persons very like, or very unlike, themselves; and from this cause there may have resulted, either an undue likeness, or a due unlikeness, between the married cousins. These several causes, conspiring and conflicting in endless ways and degrees, will work multiform effects. Moreover, differences of segregation will make the reproductive centres produced by the same nearly-related organisms, vary considerably in their amounts of unlikeness; and therefore, supposing their amounts of unlikeness great enough to cause fertilization, this fertilization will be effective in various degrees. Hence it may happen that among offspring of nearly-related parents, there may be some in which the want of vigour is not marked, and others in which there is decided want of vigour. So that we are alike shown why in-and-in breeding tends to diminish both fertility and vigour; and why the effect cannot be a uniform effect, but only an average effect.

§ 96. While, if the foregoing arguments are valid, gamogenesis has for its main end, the initiation of a new development by the overthrow of that approximate equilibrium arrived at among the molecules of the parent-organisms; a further end appears to be subserved by it. Those inferior organisms which habitually multiply by agamogenesis, have conditions of life that are simple and uniform; while those organisms that have highly-complex and variable conditions of life, habitually multiply by gamogenesis. Now if a species has complex and variable conditions of life, its members must be severally exposed to sets of conditions that are slightly different: the aggregates of incident forces cannot be alike for all the scattered individuals. Hence, as functional deviation must ever be inducing structural deviation, each individual throughout the area occupied, tends to become fitted for the particular habits which its particular conditions necessitate; and in so far, *unfitted* for the average habits proper to the species. But these undue specializations are continually checked by gamogenesis. As Mr Darwin remarks —"intercrossing plays a very important part in nature in

equal force—no force which can set up a new evolution among the units of any other.

And so we reach the remarkable conclusion, that the life of a species, like the life of an individual, is maintained by the unequal and ever-varying actions of incident forces on its different parts. An individual homogeneous throughout, and having its substance everywhere continuously subject to like actions, could undergo none of those changes which life consists of; and similarly, an absolutely-uniform species, having all its members exposed to identical influences, would be deprived of that initiator of change which maintains its existence as a species. Just as, in each organism, incident forces constantly produce divergences from the mean state in various directions, which are constantly balanced by opposite divergences indirectly produced by other incident forces; and just as the combination of rhythmical functions thus maintained, constitutes the life of the organism; so, in a species, there is, through gamogenesis, a perpetual neutralization of those contrary deviations from the mean state, which are caused in its different parts by different sets of incident forces; and it is similarly by the rhythmical production and compensation of these contrary deviations, that the species continues to live. The moving equilibrium in a species, like the moving equilibrium in an individual, would rapidly end in complete equilibration, or death, were not its continually-dissipated forces continually re-supplied from without. Besides owing to the external world, those energies which, from moment to moment, keep up the lives of its individual members; every species owes to certain more indirect actions of the external world, those energies which enable it to perpetuate itself in successive generations.

§ 97. What evidence still remains, may be conveniently woven up along with a recapitulation of the argument pursued through the last three chapters. Let us contemplate the facts in their synthetic order.

That compounding and re-compounding through which we pass from the simplest inorganic substances to the most complex organic substances, has several concomitants. Each successive stage of composition, presents us with atoms that are severally larger or more integrated, that are severally more heterogeneous, that are severally more unstable, and that are more numerous in their kinds (*First Principles*, § 111). And when we come to the substances of which living bodies are formed, we find ourselves among multiplied, divergent groups and sub-groups of compounds, the units of which are large, heterogeneous, and unstable, in high degrees. There is no reason to assume that this process ends with the formation of those complex colloids which characterize organic matter. A more probable assumption is, that out of the complex colloidal atoms, there are evolved, by a still further integration, atoms that are still more heterogeneous, and of kinds that are still more multitudinous. What must be their properties? Already the colloidal atoms are extremely unstable—capable of being variously modified in their characters by very slight incident forces; and already the complexity of their polarities prevents them from readily falling into those positions of polar equilibrium which result in crystallization. Now the organic atoms composed of these colloidal atoms, must be similarly characterised in far higher degrees. Far more numerous must be the minute changes that can be wrought in them by minute external forces; far more free must they remain for a long time to obey forces tending to re-distribute them; and far greater must be the number of their kinds.

Setting out with these physiological units, the existence of which various organic phenomena compel us to recognise, and the production of which the general law of Evolution thus leads us to anticipate; we get an insight into the phenomena of Genesis, Heredity, and Variation. If each organism is built of certain of these highly-plastic units peculiar to its species—units which slowly work towards an equilibrium of their complex polarities, in producing an aggregate of the specific structure, and which are at the same time slowly modifiable by the re-actions of this aggregate—we see why the multiplication of organisms proceeds in the several ways, and with the various results, which naturalists have observed.

Heredity, as shown not only in the repetition of the specific structure, but in the repetition of ancestral deviations from it, becomes a matter of course; and it falls into unison with the fact that, in various simple organisms, lost parts can be replaced, and that, in still simpler organisms, a fragment can develop into a whole.

While an aggregate of physiological units continues to grow, by the assimilation of matter which it moulds into other units of like type; and while it continues to undergo changes of structure; no equilibrium can be arrived at between the whole and its parts. Under these conditions, then, an un-differentiated portion of the aggregate—a group of physiological units not bound up into a specialised tissue—will be able to arrange itself into the structure peculiar to the species; and will so arrange itself, if freed from controlling forces, and placed in fit conditions of nutrition and temperature. Hence the continuance of agamogenesis in little-differentiated organisms, so long as assimilation continues to be greatly in excess of expenditure.

But let growth be checked and development approach its completion—let the units of the aggregate be severally exposed to an almost constant distribution of forces; and they must begin to equilibrate themselves. Arranged as they will gradually be, into comparatively stable attitudes in relation to each other, their mobility will diminish; and groups of them, partially or wholly detached, will no longer readily re-arrange themselves into the specific form. Agamogenesis will be no longer possible; or, if possible, will be no longer easy.

When we remember that the force which keeps the Earth in its orbit, is the gravitation of each particle in the Earth towards every one of the group of particles existing 91,000,000 of miles off; we cannot reasonably doubt, that each unit in

Bearing in mind that the slightly-different orders of physiological units which an organism inherits from its parents, are subject to the same set of forces; and that when the organism is fully developed, this set of forces, becoming constant, tends slowly to re-mould the two orders of units into the same form; we see how it happens that self-fertilization becomes impossible in the higher organisms, while it remains possible in the lower organisms. In long-lived creatures that have tolerably-definite limits of growth, this assimilation of the somewhat-unlike physiological units, is liable to go on to an appreciable extent; whereas in organisms which do not continuously subject their component units to constant forces, there will be much less of this assimilation. And where the assimilation is not considerable, the segregation of mixed units, may cause the sperm-cells and germ-cells developed in the same individual, to be sufficiently different to produce, by their union, fertile germs; and several generations of self-fertilizing descendants may succeed one another, before the two orders of units have had their unlikenesses so far diminished, that they will no longer do this. The same principles explain for us the variable results of union between nearly-related organisms. According to the contrasts among the physiological units they inherit from parents and ancestors; according to the unlike proportions of the contrasted units which they severally inherit; and according to the degrees of segregation of such units in different sperm-cells and germ-cells; it may happen that two kindred individuals will produce the ordinary number of offspring, or will produce none; or will at one time be fertile and at another not; or will at one time have offspring of tolerable strength, and at another time feeble offspring.

To the like causes are also ascribable the phenomena of Variation. These are unobtrusive while the tolerably-uniform conditions of a species maintain tolerable uniformity among the physiological units of its members; but they become obtrusive when differences of conditions, entailing considerable functional differences, have entailed decided differences among the physiological units; and when the different physiological units, differently mingled in every individual, come to be variously segregated and variously combined.

Did space permit, it might be shown that this hypothesis is a key to many further facts—to the fact that mixed races are comparatively plastic under new conditions; to the fact that pure races show predominant influences when crossed with mixed races; to the fact that while mixed breeds are often of larger growth, pure breeds are the more hardy—have functions less-easily thrown out of balance. But without further argument, it will, I think, be admitted, that the power of this hypothesis to explain so many phenomena, and to bring under a common bond phenomena that seem so little allied, is strong evidence of its truth. And such evidence gains greatly in strength on observing that this hypothesis brings the facts of Genesis, Heredity, and Variation into harmony with first principles. When we see that these plastic physiological units, which we find ourselves obliged to assume, are just such more integrated, more heterogeneous, more unstable, and more multiform atoms, as would result from continuance of the steps through which organic matter is reached—when we see that the differentiations of them assumed to occur in differently-conditioned aggregates, and the equilibrations of them assumed to occur in aggregates which maintain constant conditions, are but corollaries from those universal principles implied by the persistence of force—when we see that the maintenance of life in the successive generations of a species, becomes a consequence of the continual incidence of new forces on the species, to replace the forces that are ever being rhythmically equilibrated in the propagation of the species—and when we thus see that these apparently-exceptional phenomena displayed in the multiplication of organic beings, fall into their places as results of the general laws of Evolution; we have weighty reasons for entertaining the hypothesis which affords us this interpretation.

CHAPTER XI.

CLASSIFICATION.

§ 98. THAT orderly arrangement of objects called Classification, has two purposes; which, though not absolutely distinct, are distinct in great part. It may be employed to facilitate identification; or it may be employed to organise our knowledge. If a librarian places his books in the alphabetical succession of the author's names, he places them in such way that any particular book may easily be found; but not in such way that books of a given nature stand together. When, conversely, he makes a distribution of books according to their subjects, he neglects various superficial similarities and distinctions, and groups them according to certain primary and secondary and tertiary attributes, which severally imply many other attributes—groups them so that any one volume being inspected, the general characters of all the neighbouring volumes may be inferred. He puts together in one great division, all works on History; in another all Biographical works; in another all works that treat of Science; in another Voyages and Travels; and so on. Each of his great groups he separates into sub-groups; as when he puts different kinds of pure Literature, under the heads of Fiction, Poetry, and the Drama. In some cases he makes sub-sub-groups; as when, having divided his Scientific treatises into abstract and concrete, putting in the one Logic and Mathematics, and in the other Physics, Astronomy, Ge-

simplicity. The first classifications are sure, therefore, to be groupings of objects that resemble each other in external or easily-perceived attributes, and attributes that are not of complex characters. Those likenesses among things which are due to their possession in common of simple obvious properties, may or may not coexist with further likenesses among them. When geometrical figures are classed as curvilinear and rectilinear, or when the rectilinear are divided into trilateral, quadrilateral, &c., the distinctions made, connote various other distinctions, with which they are necessarily bound up; but if liquids be classed according to their visible characters—if water, alcohol, sulphuret of carbon, &c., be grouped as colourless and transparent, we have things placed together which are unlike in their essential natures. Thus, where the objects classed have numerous attributes, the probabilities are, that the early classifications, based on simple and manifest attributes, unite under the same head many objects that have no resemblances in the majority of their attributes. As the knowledge of objects increases, it becomes possible to make groups of which the members have more numerous properties in common; and to ascertain what property, or combination of properties, is most characteristic of each group. And the classification eventually arrived at, is one in which the segregation has been carried so far, that the objects integrated in each group have more attributes in common with one another, than they have in common with any excluded objects; one in which the groups of such groups are integrated on the same principle; and one in which the degrees of differentiation and integration are proportioned to the degrees of intrinsic unlikeness and likeness. And the ultimate classification, while it serves most completely to identify the things, serves also to express the greatest amount of knowledge concerning the things—enables us to predicate the greatest number of facts concerning each thing; and by so doing proves that it expresses the most precise correspondence between our conceptions and the realities.

§ 99. Biological classifications illustrate well these phases, through which classifications in general necessarily pass. In early attempts to arrange organic beings in some systematic manner, we see at first, a guidance by conspicuous and simple characters, and a tendency towards arrangement in linear order. In successively later attempts, we see more regard paid to combinations of characters which are essential but often inconspicuous; and a gradual abandonment of a linear arrangement for an arrangement in divergent groups and re-divergent sub-groups.

In the popular mind, plants are still classed under the heads of Trees, Shrubs, and Herbs; and this serial classing according to the single attribute of magnitude, swayed the earliest observers. They would have thought it absurd to call a bamboo, thirty feet high, a kind of grass; and would have been incredulous if told that the Hart's-tongue should be placed in the same great division with the Tree-ferns. The zoological classifications that were current before Natural History became a science, had divisions similarly superficial and simple. Beasts, Birds, Fishes, and Creeping-things, are names of groups marked off from one another by conspicuous differences of appearance and modes of life—creatures that walk and run, creatures that fly, creatures that live in the water, creatures that crawl. And these groups were thought of in the order of their importance.

The first arrangements made by naturalists were based either on single characters, or on very simple combinations of characters. Describing plant-classifications, Lindley says: — "Rivinus invented, in 1690, a system depending upon the formation of the corolla; Kamel, in 1693, upon the fruit alone; Magnol, in 1720, on the calyx and corolla; and finally, Linnæus, in 1731, on variations in the stamens and pistil." In this last system, which has been for so long current as a means of identification, simple external attributes are still depended on; and an arrangement, in great measure serial, is based on the degrees in which these attributes are possessed. In 1703, some thirty years before the time of Linnæus, our countryman Ray had sketched the outlines of a more advanced system. He said that—

Plants are either
    Flowerless, or
    Flowering; and these are
        Dicotyledones, or
        Monocotyledones.

Among the minor groups which he placed under these general heads, "were Fungi, Mosses, Ferns, Compositæ, Cichoraceæ Umbelliferæ, Papilionaceous plants, Coniferæ, Labiatæ, &c., under other names, but with limits not very different from those now assigned to them." Being much in advance of his age, Ray's ideas remained dormant until the time of Jussieu; by whom they were developed into what has become known as the Natural System. Passing through various modifications in the hands of successive botanists, the Natural System has now taken the following form; which I copy (adding the alliances to the classes) from Prof. Lindley's *Vegetable Kingdom*.*

* From this table I have omitted the class *Rhizogens*, which other botanists do not agree with Lindley in regarding as a separate class. The plants respecting which there has arisen this difference of opinion, are certain flowering plants, which grow parasitically on the roots of trees. The reasons assigned by Endlicher and Lindley, for erecting them into a separate group of Phænogams, are, that in place of true leaves they have only cellular scales; that the stem is an amorphous fungous mass, imperfectly supplied with spiral vessels; and that they are without chlorophyll. Mr Griffith and Dr Hooker, however, have given preponderating reasons why they should be restored to the class Exogens. It seems here worth remarking, that certain zoological facts suggest an explanation of these anomalous botanical facts; and confirm the conclusion reached by Dr Hooker and Mr Griffith. It very commonly happens that animal-parasites are aberrant forms of the types to which they belong; and, by analogy, we may not unreasonably expect to find among parasitic plants, the most aberrant forms of vegetal types. More than this is true. The kind of aberration which we see in the one case, we see in the other; and in both cases, the meaning of the aberration is manifest. In such *Epizoa* as the *Lernæa*, the Crustacean type is disguised by the almost entire loss of the limbs and organs of sense, by the simplification of the digestive apparatus, and by the great development of the reproductive system;

same principle of co-ordination would be still further manifested. On studying the definitions of these primary, secondary, and tertiary classes, it will be found that the largest are marked off from each other by some attribute which connotes sundry other attributes; that each of the smaller classes comprehended in one of these largest classes, is marked off in a similar way from the smaller classes bound up with it; and that so, each successively smaller class, has an increased number of co-existing attributes.

§ 100. Zoological classification has had a parallel history. The first attempt which we need notice, to arrange animals in such a way as to display their affinities, is that of Linnæus. He grouped them thus:*—

CL. 1. MAMMALIA. *Ord.* Primates, Bruta, Feræ, Glires, Pecora, Belluæ, Cete.

CL. 2. AVES. *Ord.* Accipitres, Picæ, Anseres, Grallæ, Gallinæ, Passeres.

CL. 3. AMPHIBIA. *Ord.* Reptiles, Serpentes, Nantes.

CL. 4. PISCES. *Ord.* Apodes, Jugulares, Thoracici, Abdominales.

CL. 5. INSECTA. *Ord.* Coleoptera, Hemiptera, Lepidoptera, Neuroptera, Diptera, Aptera.

CL. 6. VERMES. *Ord.* Intestina, Mollusca, Testacea, Lithophyta, Zoophyta.

This arrangement of classes, is obviously based on apparent gradations of rank; and the placing of the orders similarly betrays an endeavour to make successions, beginning with the most superior forms and ending with the most inferior forms. While the general and vague idea of perfection, determines the leading character of the classification, its detailed groupings are determined by the most conspicuous external attributes. Not only Linnæus, but his opponents, who proposed other systems, were "under the impression that animals were to be arranged together into classes, orders, genera, and species, according to their more or less close external resemblance." This conception survived till the time of Cuvier. "Naturalists,"

* This classification, and the three which follow it, I quote (abridging some of them) from Prof. Agassiz's "Essay on Classification."

says Agassiz, "were bent upon establishing one continual uniform series to embrace all animals, between the links of which it was supposed there were no unequal intervals. The watchword of their school was: *Natura non facit saltum.* They called their system *la chaine des êtres.*"

The classification of Cuvier, based on internal organization instead of external appearance, was a great advance. He asserted that there are four principal forms, or four general plans, on which animals are constructed; and in pursuance of this assertion, he drew out the following scheme.

First Branch. ANIMALIA VERTEBRATA

CL. 1. MAMMALIA.
CL. 2. BIRDS.
CL. 3. REPTILIA.
CL. 4. FISHES.

Second Branch. ANIMALIA MOLLUSCA.

CL. 1. CEPHALAPODA.
CL. 2. PTEROPODA.
CL. 3. GASTEROPODA.
CL. 4. ACEPHALA.
CL. 5. BRACHIOPODA.
CL. 6. CIRRHOPODA.

Third Branch. ANIMALIA ARTICULATA.

CL. 1. ANNELIDES.
CL. 2. CRUSTACEA.
CL. 3. ARACHNIDES.
CL. 4. INSECTS.

Fourth Branch. ANIMALIA RADIATA.

CL. 1. ECHINODERMS.
CL. 2. INTESTINAL WORMS.
CL. 3. ACALEPHÆ.
CL. 4. POLYPI.
CL. 5. INFUSORIA.

But though Cuvier emancipated himself from the conception of a serial progression throughout the Animal Kingdom; sundry of his contemporaries and successors remained fettered by the old error. Less regardful of the differently-co-ordinated sets of attributes displayed by the different sub-kingdoms; and swayed by the belief in a progressive development, which was erroneously supposed to imply the possibility of arranging animals in a linear series; they persisted in thrusting organic forms into a quite unnatural order. The following classification of Lamarck illustrates this.

INVERTEBRATA.

I. Apathetic Animals. Cl. 1. Infusoria. Cl. 2. Polypi. Cl. 3. Radiaria. Cl. 4. Tunicata. Cl. 5. Vermes.	Do not feel, and move only by their excited irritability. No brain, not elongated medullary mass; no senses; forms varied; rarely articulations.
II. Sensitive Animals. Cl. 6. Insects. Cl. 7. Arachnids. Cl. 8. Crustacea. Cl. 9. Annelids. Cl. 10. Cirripeds. Cl. 11. Conchifera. Cl. 12. Mollusks.	Feel, but obtain from their sensations only perceptions of objects, a sort of simple ideas, which they are unable to combine to obtain complex ones. No vertebral column; a brain and mostly an elongated medullary mass; some distinct senses; muscles attached under the skin; form symmetrical, the parts being in pairs.

VERTEBRATA.

III. Intelligent Animals. Cl. 13. Fishes. Cl. 14. Reptiles. Cl. 15. Birds. Cl. 16. Mammalia	Feel; acquire preservable ideas; perform with them operations by which they obtain others; are intelligent in different degrees. A vertebral column; a brain and a spinal marrow; distinct senses; the muscles attached to the internal skeleton; form symmetrical, the parts being in pairs.

tions existing among the several great groups of the animal kingdom, by placing these groups at the ends of four or five radii, diverging from a centre. The diagram I cannot obtain; but in the published reports of his lectures at the School of Mines the groups were arranged thus:—

VERTEBRATA

(*Abranchiata*)
Mammalia
Aves
Reptilia
(*Branchiata*)
Amphibia
Pisces

MOLLUSCA

Cephalopoda
Heteropoda
Gasteropoda-dioecia
Pulmonata
Pteropoda
Gasteropoda-monoecia
Lamellibranchiata

ANNULOSA

Articulata
Insecta
Arachnida
Myriapoda
Crustacea

Annuloida
Annellata
Scolecida
Echinodermata
Trematoda
Rotifera
Tæniadæ
Turbellaria
Nematoidea

CŒLENTERATA

Hydrozoa
Actinozoa.

PROTOZOA

Infusoria
Spongiadæ
Gregarinidæ
Noctilucida
Foraminifera
Thalassicollida

What remnant there may seem to be of linear succession in some of these sub-groups, is merely an accident of typographical convenience. Each of them is to be regarded simply as a cluster. Were Prof. Huxley now to revise this scheme, he would probably separate more completely some of the great sub-groups, in conformity with the views expressed in his Hunterian Lectures delivered at the College of Surgeons in 1863. And if he were further to develop the arrangement, by dispersing the sub-groups and sub-sub-groups on the same principle, there would result an arrangement perhaps not very much unlike that shown in the annexed diagram.

In this diagram, the dots represent orders, the names of which it is impracticable to insert. If it be supposed that when magnified, each of these dots resolves itself into a cluster of clusters, representing genera and species, an approximate idea will be formed of the relations among the successively-subordinate groups constituting the animal kingdom. Besides the subordination of groups and their general distribution, some other facts are indicated. By the distances of the great divisions from the general centre, are rudely symbolized their respective degrees of divergence from the form of simple, undifferentiated organic matter; which we may regard as their common source. Within each group, the remoteness from the local centre represents, in a rough way, the degree of departure from the general plan of the group. And the distribution of the sub-groups within each group, is in most cases such, that those which come nearest to neighbouring groups, are those which show the nearest resemblances to them—in their analogies though not in their homologies. No diagram, however, can give a correct conception. Even supposing the above diagram expressed the relations of animals to one another as truly as they can be expressed on a plane surface, (which of course it does not,) it would still be inadequate. Such relations cannot be represented in space of two dimensions; but only in space of three dimensions

§ 101. While the classifications of botanists and zoologists have become more and more natural in their arrangements, there has grown up a certain artificiality in their abstract nomenclature. When aggregating the smallest groups into larger groups, and these into groups still larger, naturalists adopted certain general terms expressive of the successively more comprehensive divisions; and the habitual use of these terms, needful for purposes of convenience, has led to the tacit assumption that they answer to actualities in Nature. It has been taken for granted that species, genera, orders, and classes, are assemblages of definite values—that every genus is the equivalent of every other genus, in respect of its degree of distinctness; and that orders are separated by lines of demarcation that are as broad in one place as another. Though this conviction is not a formulated one, yet the disputes continually arising among naturalists on the

attributes which are common to the members of any group of the first, second, third, or fourth rank, we see that groups of the widest generality are based on characteristics of the greatest importance, physiologically considered; and that the characteristics of the successively-subordinate groups, are characteristics of successively-subordinate importance. The structural peculiarity in which all members of one sub-kingdom differ from all members of another sub-kingdom, is a peculiarity that affects the vital actions more profoundly, than does the structural peculiarity which distinguishes all members of one class from all members of another class. Let us look at a few cases.

We saw (§ 56), that the broadest division among the functions is the division into "the *accumulation of force* (latent in food); the *expenditure of force* (latent in the tissues and certain matters absorbed by them); and the *transfer of force* (latent in the prepared nutriment or blood) from the parts which accumulate to the parts which expend." Now the lowest animals, united under the general name *Protozoa*, are those in which there is either no separation of the parts performing these functions or very indistinct separation: in the *Rhizopoda*, all parts are alike accumulators of force, expenders of force, and transferrers of force; and though in the most differentiated members of the group, the *Infusoria*, there are something like specializations corresponding to these functions, yet there are no distinct tissues appropriated to them. The animals known as *Cœlenterata* are characterized in common by the possession of a part which accumulates force more or less marked off from the part which does not accumulate force, but only expends it; and the *Hydrozoa* and *Actinozoa*, which are sub-divisions of the *Cœlenterata*, are contrasted in this, that in the one these parts are very indefinitely distinguished, but in the other definitely separated, as well as more complicated. Besides a completer differentiation of the organs respectively devoted to the accumulation of force and the expenditure of force, the animals classed as *Molluscoida*, possess rude appliances for the transfer of force: the peri-visceral sac, or closed cavity between the intestine and the walls of the body, serves as a reservoir of absorbed nutriment, from which the surrounding tissues take up the materials they need. The more highly-organized animals, belonging to whichever sub-kingdom, all of them possess definitely-constructed channels for the transfer of force; and in all of them, the function of expenditure is divided between a directive apparatus and an executive apparatus—a nervous system and a muscular system. But these higher sub-kingdoms are clearly separated from each other by differences in the relative positions of their component sets of organs. Prof. Huxley defines the type of the *Vertebrata*, as one in which the ganglionic nervous system lies on the dorsal side of the alimentary canal, while the central vascular system lies on its ventral side; and one which is yet further characterized by the possession of a second, and more conspicuous, nervous system, placed on the dorsal side of the vertebral axis—an extra endowment which is perhaps the most essentially distinctive. The types of the *Annulosa* and *Mollusca*, are together marked off from the vertebrate type, by the singleness of the nervous system, and by its occupation of the ventral side of the body: the habitual attitudes of annulose and molluscous creatures, is such that the neural centres are below the alimentary canal and the hæmal centres above. And while by these traits the annulose and molluscous types are separated from the vertebrate, they are separated from each other by this, that in the one the body is "composed of successive segments, usually provided with limbs," but the other, the body is not segmented, "and no true articulated limbs are ever developed."

The sub-kingdoms being thus distinguished from one another, by the presence or absence of parts devoted to fundamental functions, or else by differences in the distributions of such parts; we find, on descending to the classes, that these are distinguished from each other, either by modifications in the structures of fundamental parts, or by the presence or absence of subsidiary parts, or by both. Fishes and *Amphibia* are unlike higher vertebrates in possessing branchiæ; either throughout life or early in life. And every higher vertebrate, besides having lungs, is characterized by having, during development, an amnion and an allantois. Mammals, again, are marked off from Birds and Reptiles by the presence of mammæ, as well as by the form of the occipital condyles. Among Mammals, the next division is based on the presence or absence of a placenta. And divisions of the *Placentalia* are mainly determined by the characters of the organs of external action.

Thus, without multiplying illustrations and without descending to genera and species, we see that, speaking generally, the successively smaller groups, are distinguished from one another by traits of successively less importance, physiologically considered. The attributes possessed in common by the largest assemblages of organisms, are few in number but all-essential in kind—affect fundamentally the most vital actions. Each secondary assemblage, included in one of the primary assemblages, is characterized by further common attributes that influence the functions less profoundly. And so on with each lower grade of assemblage.

§ 103. What interpretation is to be put on these truths of classification? We find that organic forms admit of an arrangement everywhere expressive of the fact, that along with certain attributes, certain other attributes, which are not directly connected with them, always exist. How are we to account for this fact? And how are we to account for the fact that the attributes possessed in common by the largest assemblages of forms, are the most vitally-important attributes?

No one can believe that combinations of this kind may have arisen fortuitously. Or if any one believes this, it is

And then, when it turns out that this possession of seven cervical vertebræ is not an absolutely-universal characteristic of mammals, shall we conclude that while, in a host of cases, there is a needless adherence to a plan for the sake of consistency, there is yet, in some cases, an inconsistent abandonment of the plan? I think we may properly refuse to draw any such conclusion.

What, then, is the meaning of these peculiar relations of organic forms? The answer to this question must be postponed. Having here contemplated the problem as presented in these wide inductions which naturalists have reached; and having seen what proposed solutions of it are inadmissible; we shall see, in the next division of this work, what is the only possible solution.

CHAPTER XII.

DISTRIBUTION.

§ 104. THERE is a distribution of organisms in Space, and there is a distribution of organisms in Time. Looking first at their distribution in Space, we observe in it two different classes of facts. On the one hand, the plants and animals of each species, manifestly have their habitats limited by external conditions: they are necessarily restricted to spaces in which their vital actions can be performed. On the other hand, the existence of certain conditions does not determine the presence of organisms that are the fittest for them: there are many spaces perfectly adapted for life of a high order, in which only life of a much lower order is found. While, in this inevitable restriction of organisms to environments with which their natures correspond, we find a *negative* cause of distribution; there remains to be found that *positive* cause of distribution, whence results the presence of organisms in some of the places appropriate to them, and their absence from other places that are equally appropriate and more appropriate. Let us consider the phenomena under these categories.

§ 105. Facts which illustrate the limiting influence of surrounding conditions, are abundant, and familiar to all readers. It will be needful, however, here to cite a few typical ones of each order.

with the influences, direct or more or less remote, of nearly all co-existing organisms.

One general truth, indicated by sundry of the above illustrations, calls for special notice—the truth that organisms are ever intruding on each other's spheres of existence. Of the various modes in which this is shown, the commonest is the invasion of territory. That tendency which we see in the human races, to overrun and occupy each other's lands, as well as the lands inhabited by inferior creatures, is a tendency exhibited by all classes of organisms in all varieties of ways. Among them, as among mankind, there are permanent conquests, temporary occupations, and occasional raids. Annual migrations are instances of this process in its most familiar form. Every spring an inroad is made into the area which our own fly-catchers occupy, by the swallows of the South; and every winter the fieldfares of the North, come to share the hips and haws of our hedges with native birds—a partial possession of their territory, which entails on our native birds, some mortality. Besides these regularly-recurring raids, there are irregular ones: as of locusts into countries not usually visited by them; or of strange birds which in small flocks from time to time visit areas adjacent to their own. Every now and then, an incursion ends in permanent settlement—perhaps in conquest over indigenous species. Within these few years, an American water-weed has taken possession of our ponds and rivers, and to some extent supplanted native water-weeds. Of animals, may be named a small kind of red ant, having habits allied to those of tropical ants, which has of late overrun many houses in London. The case of the rat, which must have taken to infesting ships within these few centuries, is a good illustration of the readiness of animals to occupy new places that are available. And the way in which vessels visiting India, are cleared of the European cockroach by the kindred *Blatta orientalis,* shows us how these successful invasions last only until there come more powerful invaders. Organ

gruous with the hypothesis, that each species was originally placed in the regions most favourable to it. But the absence of a species from regions that *are* favourable to it, cannot be thus accounted for. Were plants and animals localised wholly with reference to the fitness of their constitutions to surrounding conditions, we might expect Floras to be similar and Faunas to be similar, where the conditions are similar; and we might expect dissimilarities among Floras and among Faunas, proportionate to the dissimilarities of their conditions. But we do not find such anticipations verified.

Mr Darwin says that "in the Southern hemisphere, if we compare large tracts of land in Australia, South Africa, and western South America, between latitudes 25° and 35°, we shall find parts extremely similar in all their conditions, yet it would not be possible to point out three faunas and floras more utterly dissimilar. Or again we may compare the productions of South America south of lat. 35° with those north of 25°, which consequently inhabit a considerably different climate, and they will be found incomparably more closely related to each other, than they are to the productions of Australia or Africa under nearly the same climate." Still more striking are the contrasts which Mr Darwin points out, between closely-adjacent areas that are totally cut-off from each other. "No two marine faunas are more distinct, with hardly a fish, shell, or crab in common, than those of the eastern and western shores of South and Central America; yet these great faunas are separated only by the narrow, but impassable, isthmus of Panama." On opposite sides of high mountain-chains, also, there are marked differences in the organic forms—differences not so marked as where the barriers are absolutely impassable; but much more marked than are necessitated by unlikenesses of physical conditions.

Not less suggestive is the converse fact, that wide geographical areas which offer decided geologic and meteorologic contrasts, are peopled by nearly-allied groups of organisms, if there are no barriers to migration. "The naturalist in travelling, for instance, from north to south never fails to be struck by the manner in which successive groups of beings, specifically distinct, yet clearly related, replace each other. He hears from closely allied, yet distinct kinds of birds, notes nearly similar, and sees their nests similarly constructed, but not quite alike, with eggs coloured in nearly the same manner. The plains near the Straits of Magellan are inhabited by one species of Rhea (American Ostrich), and north-ward the plains of La Plata by another species of the same genus; and not by a true ostrich or emeu, like those found in Africa and Australia under the same latitude. On these same plains of La Plata, we see the agouti and bizcacha, animals having nearly the same habits as our hares and rabbits and belonging to the same order of Rodents, but they plainly display an American type of structure. We ascend the lofty peaks of the Cordillera and we find an alpine species of bizcacha; we look to the waters, and we do not find the beaver or musk-rat, but the coypu and capybara, rodents of the American type. Innumerable other instances could be given. If we look to the islands off the American shore, however much they may differ in geological structure, the inhabitants, though they may be all peculiar species, are essentially American."

What is the generalization that expresses these two groups of facts? On the one hand, we have similarly-conditioned, and sometimes nearly-adjacent, areas, occupied by quite different Faunas. On the other hand, we have areas remote from each other in latitude, and contrasted in soil as well as climate, which are occupied by closely-allied Faunas. Clearly then, as like organisms are not universally, or even generally, found in like habitats; nor very unlike organisms, in very unlike habitats; there is no manifest pre-determined adaptation of the organisms to the habitats. The organisms do not occur in such and such places, solely because they are either specially fit for these places, or more fit for them than all other organisms.

The induction under which these facts come, and which unites them with various other facts, is a totally-different one. When we see that the similar areas peopled by dissimilar forms, are those between which there are impassable barriers; while the dissimilar areas peopled by similar forms, are those between which there are no such barriers; we are at once reminded of the general truth exemplified in the last section:—the truth that each species of organism, tends ever to expand its sphere of existence—to intrude on other areas, other modes of life, other media; and through these perpetually-recurring attempts to thrust itself into every accessible habitat, spreads until it reaches limits that are for the time insurmountable.

§ 107. We pass now to the distribution of organic forms in Time. Geological inquiry has established the truth, that during a Past of immeasurable duration, plants and animals have existed on the Earth. In all countries their buried remains are found in greater or less abundance. From comparatively small areas, multitudinous different forms have been exhumed. Every exploration of new areas, and every closer inspection of areas already explored, brings more such forms to light. And beyond question, an exhaustive examination of all exposed strata, and of all strata now covered by the sea, would disclose forms immensely out-numbering all those at present known. Further, it is now becoming manifest to geologists, that even had we before us every kind of fossil which exists, we should still have nothing like a complete index to the past inhabitants of our globe. It has been long known that many sedimentary deposits have been so altered by the heat of adjacent molten matter, as greatly to obscure the organic remains contained in them. The extensive formations once called "transition," and now re-named "metamorphic," are acknowledged to be formations of sedimentary origin, from which all traces of such fossil as they probably included, have been obliterated by igneous action. And the conclusion forcing itself into acceptance, is, that igneous rock

thus arise gradually or all at once, in formations that are continuous or discontinuous, are of two kinds. Faunas of different eras, are distinguished partly by the absence from one of types that are present in the other; and partly by the unlikenesses between the types that are common to both. Such distinctions between Faunas as are due to the appearance or disappearance of types, are of secondary significance: they possibly, or probably, do not imply anything more than migrations or extinctions. The most significant distinctions are those between successive groups of organisms of the same type. And among such, as above said, the differences that arise are, speaking generally, small and continuous where a series of conformable strata gives proof of continued existence of the type in the locality; while they are comparatively large and abrupt, where there is evidence that between the deposit of the adjacent formations, a long period elapsed.

Another general fact, referred to by Mr Darwin as one which palæontology has made tolerably certain, is that forms and groups of forms which have once disappeared from the Earth, do not reappear. Some few species and a good many genera, have continued throughout the whole period geologically recorded. But omitting these as exceptional, it may be said that each species after arising, spreading for an era, and continuing abundant for an era, eventually declines and becomes extinct; and that similarly, each genus during a longer period increases in the number of its species, and during a longer period dwindles and at last dies out. Having made its exit, neither species nor genus ever re-enters. And the like is true, even of those larger groups called orders. Four types of reptiles that were once abundant, have not been found in modern formations, and do not at present exist. Though nothing less than an exhaustive examination of all strata, can prove conclusively that a special or general form of organization when once lost is never reproduced; yet so many facts point to this inference, that its truth can scarcely be doubted.

To form a conception of the total amount and general direction of the change that has arisen in organic forms during the geologic time measured by our sedimentary series, is at present impossible—the data are insufficient. The immense contrast between the few and low forms of the earliest-known Fauna, and the many and high forms of our existing Fauna, has been commonly supposed to prove, not only great change but great progress. Nevertheless, this appearance of progress may be, and probably is, mainly illusive. Wider knowledge and increased power of interpretation, have made it manifest that remains of comparatively well-organized creatures, really existed in strata long supposed to be devoid of them; and that where they are actually absent, the nature of the strata often supplies a sufficient explanation of their absence, without assuming that they did not exist when these strata were formed. It has now become a tenable hypothesis, that the successively-higher types fossilized in our successively-later deposits, indicate nothing more than successive migrations from pre-existing continents, to continents that were step by step emerging from the ocean—migrations which necessarily began with the inferior orders of organisms, and included the successively-superior orders as the new lands became more accessible to them, and better fitted for them.*

While the evidence usually supposed to prove progression, is thus untrustworthy, there is trustworthy evidence that there has been, in many cases, little or no progression. Though the types which have existed from palæozoic and mesozoic times down to the present day, are almost universally changed; yet a comparison of ancient and modern members of these types, shows that the total amount of change is not relatively great, and that it is not manifestly towards a higher organization. Though nearly all the living forms which have prototypes in early formations, differ from these prototypes specifically, and in most cases generically; yet ordinal peculiarities are, in very numerous cases, maintained from the earli-

* For explanations, see "Illogical Geology." *Essays: Second Series.*

est times geologically recorded, down to our own time; and we have no visible evidence of superiority in the existing genera of these orders. In his lecture "On the Persistent Types of Animal Life," Prof. Huxley enumerates many cases. On the authority of Dr. Hooker, he stated "that there are Carboniferous plants which appear to be generically identical with some now living; that the cone of the Oolitic *Araucaria* is hardily distinguishable from that of an existing species; that a true *Pinus* appears in the Purbecks and a *Juglans* in the chalk." Among animals he named palæozoic and mesozoic corals which are very like certain extant corals; genera of Silurian molluscs that answer to existing genera; insects and arachnids in the coal formations, that are not more than generically different from some of our own insects and arachnids. He instanced "the Devonian and Carboniferous *Pleuracanthus*, which differs no more from existing sharks than these do from one another;" early mesozoic reptiles "identical in the essential characters of their organization with those now living;" and Triassic mammals which did not differ "nearly so much from some of those which now live, as these differ from one another." Continuing the argument in his "Anniversary Address to the Geological Society" in 1862, Prof. Huxley gave many cases in which the changes that have taken place, are not changes towards a more specialized or higher organization—asking "in what sense are the Liassic Chelonia inferior to those which now exist? How are the Cretaceous Ichthyosauria, Plesiosauria, or Pterosauria less embryonic or more differentiated species than those of the Lias?" While, however, contending that in most instances "positive evidence fails to demonstrate any sort of progressive modification towards a less embryonic or less generalized type in a great many groups of animals of long-continued geological existence;" Prof. Huxley added, that there are other groups "co-existing with them, under the same conditions, in which more or less distinct indications of such a process seem to be traceable." And in illustration of this, he named that better

original type. That which Prof. Huxley's argument proves, and that only which he considers it to prove, is that organisms have no innate tendencies to assume higher forms, and that "any admissible hypothesis of progressive modification, must be compatible with persistence without progression through indefinite periods."

One very significant fact must be added, concerning the relation between distribution in Time and distribution in Space. I quote it from Mr Darwin :—"Mr Clift many years ago showed that the fossil mammals from the Australian caves were closely allied to the living marsupials of that continent. In South America, a similar relationship is manifest, even to an uneducated eye, in the gigantic pieces of armour like those of the armadillo, found in several parts of La Plata; and Professor Owen has shown in the most striking manner that most of the fossil mammals, buried there in such numbers, are related to the South American types. This relationship is even more clearly seen in the wonderful collection of fossil bones made by MM. Lund and Clausen in the caves of Brazil. I was so much impressed with these facts that I strongly insisted, in 1839 and 1845, on this 'law of the succession of types,'—on 'this wonderful relationship in the same continent between the dead and the living.' Professor Owen has subsequently extended the same generalization to the mammals of the Old World. We see the same law in this author's restorations of the extinct and gigantic birds of New Zealand. We see it also in the birds of the caves of Brazil. Mr Woodward has shown that the same law holds good, with sea-shells, but from the wide distribution of most genera of molluscs, it is not well displayed by them. Other cases could be added, as the relation between the extinct and living land-shells of Madeira; and between the extinct and living brackish-water shells of the Aralo-Caspian Sea.'"

The general results then, are these. Our knowledge of distribution in Time, being derived wholly from the evidence afforded by fossils, is limited to that geologic time of which some records remain: cannot extend to those pre-geologic times the records of which have been obliterated. From these remaining records, which probably form but a small fraction of the whole, the general facts deducible are:—That such organic types as have lived through successive epochs, have almost universally undergone modifications of specific and generic values—modifications which have commonly been great in proportion as the period has been long. That besides the types that have persisted from ancient eras down to our own era, other types have from time to time made their appearance in the ascending series of our strata—types of which some are lower and some higher than the types previously recorded; but whence these new types came, and whether any of them arose by divergence from the previously-recorded types, the evidence does not yet enable us to say. That in the course of long geologic epochs, nearly all species, most genera, and a few orders, become extinct; and that a species, genus, or order, which has once disappeared from the Earth, never reappears. And, lastly, that the Fauna now occupying each separate area of the Earth's surface, is very nearly allied to the Fauna which existed on that area during recent geologic times.

§ 108. Omitting sundry minor generalizations, the exposition of which would involve too much detail, what is to be said of these major generalizations?

The distribution in Space cannot be said to imply that organisms have been designed for their particular habitats, and placed in them; since, besides the habitat in which an organism is found there are commonly other habitats, as well or better for it, from which it is absent—habitats to which it is so much better fitted than organisms now occupying them, that it extrudes these organisms when allowed the opportunity. Neither can we suppose that one end has been to establish varieties of Floras and Faunas; since, if so, why are the Floras and Faunas but little divergent in widely-sundered areas between which migration is possible, while they are markedly divergent in adjacent areas between which migration is impossible?

Passing to distributions in Time, there arise the questions—why during nearly the whole of that vast period geologically recorded, have there existed none of those highest organic forms which have now overrun the Earth?—how is it that we find no traces of a creature endowed with large capacities for knowledge and happiness? The answer that the Earth was not, in remote times, a fit habitation for such a creature, besides being unwarranted by the evidence, suggests the equally awkward question—why during untold millions of years did the Earth remain fit only for inferior creatures? What, again, is the meaning of this extinction of types? To conclude that the saurian type was replaced by other types at the beginning of the tertiary period, because this type was not adapted to the conditions which then arose, is to conclude that this type could not be modified into fitness for the conditions; and this conclusion is quite at variance with the hypothesis that creative skill is shown in the multiform adaptations of one type to many ends.

What interpretations may rationally be put on these and other general facts of distribution in Space and Time, we shall see in the next division of this work; to which let us now pass.

CHAPTER I.

PRELIMINARY.

§ 109. In the foregoing Part, we have contemplated the most important of the generalizations to which biologists have been led by observation of organisms. These Inductions of Biology have also been severally glanced at on their deductive sides; for the purpose of noting the harmony that exists between them, and those primordial truths set forth in *First Principles.* Having thus studied the leading phenomena of life separately, we are prepared for studying them in their *ensemble,* with the view of arriving at the most general interpretation of them.

There is an *ensemble* of vital phenomena presented by each organism in the course of its growth, development, and decay; and there is an *ensemble* of vital phenomena presented by the organic world as a whole. Neither of these can be properly dealt with apart from the other. But the last of them may be separately treated more conveniently than the first. What interpretation we put on the facts of structure and function in each living body, depends entirely on our conception of the mode in which living bodies in general have originated. To form some conclusion respecting this mode—a provisional if not a permanent conclusion—must therefore be our first step.

We have to choose between two hypotheses—the hypothesis of Special Creation and the hypothesis of Evolution.

Either the multitudinous kinds of organisms that now exist, and the still more multitudinous kinds that have existed during past geologic eras, have been from time to time separately made; or they have arisen by insensible steps, through actions such as we see habitually going on. Both hypotheses imply a Cause. The last, certainly as much as the first, recognizes this Cause as inscrutable. The point at issue is, how this inscrutable Cause has worked in the production of living forms. This point, if it is to be decided at all, is to be decided only by examination of evidence. Let us inquire which of these antagonist hypotheses is most congruous with established facts.

were at first wrong. In all these cases men set out with beliefs which, if not absolutely false, contained but small amounts of truth disguised by immense amounts of error.

Hence the hypothesis that living beings resulted from special creations, being a primitive hypothesis, is probably an untrue hypothesis. If the interpretations of Nature given by aboriginal men, were erroneous in other directions, they were most likely erroneous in this direction. It would be strange if, while these aboriginal men failed to reach the truth in so many cases where it is comparatively conspicuous, they yet reached the truth in a case where it is comparatively hidden.

§ 111. Besides the improbability given to the belief in special creations, by its association with mistaken early beliefs in general; a further improbability is given to it by its association with a special class of mistaken beliefs. It belongs to a family of beliefs which have one after another been destroyed by advancing knowledge; and is, indeed, almost the only member of the family that survives among educated people.

We all know that the savage thinks of each striking phenomenon, or group of phenomena, as caused by some separate personal agent; that out of this fetishistic conception there grows up a polytheistic conception, in which these minor personalities are variously generalized into deities presiding over different divisions of nature; and that these are eventually further generalized. This progressive consolidation of causal agencies, may be traced in the creeds of all races; and is far from complete in the creeds of the most advanced races. The unlettered rustics who till our fields, do not let the consciousness of a supreme power wholly absorb the aboriginal conceptions of good and evil spirits, and charms or secret potencies dwelling in particular objects. The earliest mode of thinking changes, only as fast as the constant relations among phenomena are established. Scarcely less familiar is the truth, that while accumulating knowledge makes these conceptions of personal causal agents gradually more vague, as it merges them into general causes, it also destroys the habit of thinking of them as working after the methods of personal agents. We do not now, like Kepler, assume guiding spirits to keep the planets in their orbits. It is no longer the universal belief that the sea was once for all mechanically parted from the dry land; or that the mountains were placed where we see them by a sudden creative act. All but a narrow class have ceased to suppose sunshine and storm to be sent in some arbitrary succession. The majority of educated people have given up thinking of epidemics as punishments inflicted by an angry deity. Nor do even the common people regard a madman as one possessed by a demon. That is to say, we everywhere see fading away the anthropomorphic conception of the Unknown Cause. In one case after another, is abandoned that interpretation which ascribes phenomena to a will analogous to the human will, working by methods analogous to human methods.

If, then, of this once-numerous family of beliefs, the immense majority have become extinct, we may not unreasonably expect that the few remaining members of the family will become extinct. One of these is the belief we are here considering—the belief that each species of organism was specially created. Many who in all else have abandoned the aboriginal theory of things, still hold this remnant of the aboriginal theory. Ask any tolerably-informed man whether he accepts the cosmogony of the Indians, or the Greeks, or the Hebrews, and he will regard the question as next to an insult. Yet one element common to these cosmogonies he very likely retains: not bearing in mind its origin. For whence did he get the doctrine of special creations? Catechise him, and he is forced to confess that it was put into his mind in childhood, as one portion of a story which, as a whole, he has long since rejected. Why this fragment is likely to be right while all the rest is wrong, he is unable to say. May we not then expect, that the relinquishment of all other parts of this story, will bye and bye be followed by the relinquishment of this remaining part of it?

§ 112. The belief which we find thus questionable, both as being a primitive belief and as being a belief belonging to an almost-extinct family, is a belief that is not countenanced by a single fact. No one ever saw a special creation; no one ever found proof of an indirect kind, that a special creation had taken place. It is significant, as Dr Hooker remarks, that naturalists who suppose new species to be miraculously originated, habitually suppose the origination to occur in some region remote from human observation. Wherever the order of organic nature is exposed to the view of zoologists and botanists, it expels this conception; and the conception survives only in connexion with imagined places, where the order of organic phenomena is unknown.

Besides being absolutely without evidence to give it external support, this hypothesis of special creations cannot support itself internally—cannot be framed into a coherent thought. It is one of those illegitimate symbolic conceptions, so continually mistaken for legitimate symbolic conceptions (*First Principles*, § 9), because they remain untested. Immediately an attempt is made to elaborate the idea into anything like a definite shape, it proves to be a pseud-idea, admitting of no definite shape. Is it supposed that a new organism, when specially created, is created out of nothing? If so, there is a supposed creation of matter; and the creation of matter is inconceivable—implies the establishment of a relation in thought between nothing and something—a relation of which one term is absent—an impossible relation. Is it supposed that the matter of which the new organism consists, is not created for the occasion, but is taken out of its pre-existing forms and arranged into a new form? If so, we are met by the question—how is the re-arrangement

ing men and women, during his few hours of life, and speculating as to the mode in which they came into existence; it is manifest that, reasoning in the usual way, he would suppose each man and woman to have been separately created. No appreciable changes of structure occurring in any of them during the few hours over which his observations extended, this being would probably infer that no changes of structure were taking place, or had taken place; and that from the outset, each man and woman had possessed all the characters then visible—had been orginally formed with them. This would naturally be the first impression. The application is obvious. A human life is ephemeral compared with the life of a species; and even the period over which the records of human experience extend, is ephemeral compared with the life of a species. There is thus a parallel contrast between the immensely-long series of changes that have occurred during the life of a species, and that small portion of the series open to our view. And there is no reason to suppose that the first conclusion drawn by mankind from this small part of the series visible to them, is any nearer the truth, than would be the conclusion of the supposed ephemeral being respecting men and women.

This analogy, suggesting as it does how the hypothesis of special creations is merely a formula for our ignorance, raises the question—what reason have we to assume special creations of species but not of individuals; unless it be that in the case of individuals we directly know the process to be otherwise, but in the case of species do not directly know it to be otherwise? Have we any ground for concluding that species were specially created, except the ground that we have no immediate knowledge of their origin? And does our ignorance of the manner in which they arose, warrant us in asserting that they arose by special creation?

Another question is suggested by this analogy. Those who, in the absence of immediate evidence of the way in which species arose, assert that they arose not in any way analogous to that in which individuals arise, but in a totally distinct way, think that by this supposition they honour the Unknown Cause of things; and they oppose any antagonist doctrine as amounting to an exclusion of divine power from the world. But if divine power is demonstrated by the separate creation of each species, would it not have been still better demonstrated by the separate creation of each individual? Why should there exist this process of natural genesis? Why should not omnipotence have been proved by the supernatural production of plants and animals everywhere throughout the world from hour to hour? Is it replied that the Creator was able to make individuals arise from one another in a natural succession, but not to make species thus arise? This is to assign a limit to power instead of magnifying it. Is it replied that the occasional miraculous origination of a species was practicable, but that the perpetual miraculous origination of countless individuals was impracticable? This also is a derogation. Either it was possible or not possible to create species and individuals after the same general method. To say that it was not possible is suicidal in those who use this argument; and if it was possible, it is required to say what end is served by the special creation of species that would not have been better served by the special creation of individuals. Again, what is to be thought of the fact that the great majority of these supposed special creations took place before mankind existed? Those who think that divine power is demonstrated by special creations, have to answer the question—to whom demonstrated? Tacitly or avowedly, they regard the demonstrations as being for the benefit of mankind. But if so, to what purpose were the millions of these demonstrations which took place on the Earth when there were no intelligent beings to contemplate them? Did the Unknowable thus demonstrate his power to himself? Few will have the hardihood to say that any such demonstration was needful. There is no choice but to regard them, either as superfluous exercises of power, which is a derogatory supposition, or as exercises of power that were necessary because species could not be otherwise produced, which is also a derogatory supposition.

§ 114. Those who espouse the hypothesis of special creations, entangle themselves in other theological difficulties. This assumption that each kind of organism was specially designed, carries with it the implication that the designer intended everything that results from the design. There is no escape from the admission, that if organisms were severally constructed with a view to their respective ends; then the character of the constructor is indicated both by the ends themselves, and the perfection or imperfection with which the organisms are fitted to them. Observe the consequences.

Without dwelling on the question put in a recent chapter, why during untold millions of years there existed on the Earth no beings endowed with capacities for wide thought and high feeling, we may content ourselves with asking why, at present, the Earth is largely peopled by creatures which inflict on each other, and on themselves, so much suffering? Omitting the human race, whose defects and miseries the current theology professes to account for, and limiting ourselves to the lower creation, what must we think of the countless different pain-inflicting appliances and instincts with which animals are endowed? Not only now, and not only ever since men have lived, has the Earth been a scene of warfare among all sentient creatures; but palæontology shows us that, from the earliest eras geologically recorded, there has been going on this universal carnage. Fossil structures, in common with the structures of existing animals, show us elaborate weapons for destroying other animals. We have unmistakable proof that throughout all past time, there has been a perpetual preying of the superior on the inferior—a ceaseless devouring of the weak

lower order. So long, too, as we leave out all mortality but that which, by carrying off the least perfect members of each species, leaves the most perfect members to continue the species; we see some compensating benefit reached through the suffering inflicted. But what shall we say on finding innumerable cases in which the suffering inflicted brings no compensating benefit? What shall we say when we see the inferior destroying the superior? What shall we say on discovering elaborate appliances for securing the prosperity of organisms incapable of feeling, at the expense of misery to organisms capable of happiness?

Of the animal kingdom as a whole, more than half the species are parasites. "The number of these parasites," says Prof. Owen, "may be conceived when it is stated that almost every known animal has its peculiar species, and generally more than one, sometimes as many as, or even more kinds than, infest the human body." Passing over the evils thus inflicted on animals of inferior dignity, let us limit ourselves to the case of man. The *Bothriocephalus latus* and the *Tænia solium*, are two kinds of tape-worm, which flourish in the human intestines; producing great constitutional disturbances, sometimes ending in insanity; and from the germs of the *Tænia*, when carried into other parts of the body, arise certain partially-developed forms known as *Cysticerci*, *Echinococci*, and *Cœnuri*, which cause disorganization more or less extensive in the brain, the lungs, the liver, the heart, the eye, &c., often ending fatally after long-continued suffering. Five other parasites, belonging to a different class, are found in the viscera of man — the *Trichocephalus*, the *Oxyuris*, the *Strongylus* (two species), the *Ancylostomum*, and the *Ascaris;* which, beyond that defect of nutrition which they necessarily cause, sometimes induce certain irritations that lead to complete demoralization. Of another class of *entozoa*, belonging to the subdivision *Trematoda*, there are five kinds found in different organs of the human body—the liver and gall ducts, the portal vein, the intestine, the bladder, the eye. Then we have the *Trichina spiralis*, which passes through one phase of its existence imbedded in the muscles and through another phase of its existence in the intestine; and which, by the induced disease *Trichiniasis*, has lately committed such ravages in Germany, as to cause a panic. And to these we must add the Guinea-worm, which in some part of Africa and India, makes men miserable by burrowing in their legs. From this list of *entozoa*, which is by no means complete, let us pass to the *epizoa*. There are two kinds of *Acari*, one of them inhabiting the follicles of the skin, and the other producing the itch. There are other creatures that bury themselves beneath the skin, and lay their eggs there; and there are three species of lice which infest the surface of the body. Nor is this all: besides animal parasites, there are sundry vegetal parasites, which grow and multiply at our cost. The *Sarcina ventriculi* inhabits the stomach, and produces gastric disturbance. The *Leptothrix buccalis* is extremely general in the mouth, and may have something to do with the decay of teeth. And besides these, there are microscopic fungi which produce ringworm, porrigo, pityriasis, thrush, &c. Thus the human body is the habitat of parasites, internal and external, animal and vegetal, numbering, if all were set down, some two or three dozen species; sundry of which are peculiar to man, and many of which produce in man great suffering and not unfrequently death. What interpretation is to be put on these facts by those who espouse the hypothesis of special creations? According to this hypothesis, all these parasites were designed with a view to their respective modes of life. They were endowed with constitutions fitting them to live by absorbing the juices of the human body; they were furnished with appliances, often of a formidable kind, enabling them to root themselves in and upon the human body; and they were made prolific in an almost incredible degree, that their germs might have a sufficient number of chances of finding their way into the human body. In short, elaborate contrivances were combined to insure the continuance of their respective races; and to make it impossible for the successive generations of men to avoid being preyed upon by them. What shall we say to this arrangement? Shall we say that man, "the head and crown of things," was provided as a habitat for these parasites? Or shall we say that these degraded creatures, incapable of thought or enjoyment, were created that they might cause unhappiness to man? One or other of these alternatives must be chosen by those who contend that every kind of organism was separately devised by the Creator. Which do they prefer? With the conception of two antagonistic powers, which severally work good and evil in the world, the facts are congruous enough. But with the conception of a supreme beneficence, this gratuitous infliction of misery on man, in common with all other terrestrial creatures capable of feeling, is absolutely incompatible.

§ 115. See then the results of our examination. The belief in special creations of organisms, is a belief that arose among men during the era of profoundest darkness; and it belongs to a family of beliefs which have nearly all died out as enlightenment has increased. It is without a solitary established fact on which to stand; and when the attempt is made to put it into definite shape in the mind, it turns out to be only a pseud-idea. This mere verbal hypothesis, which men idly accept as a real or thinkable hypothesis, is of the same nature as would be one, based on a day's observation of human life, that each man and woman was specially created—an hypothesis not suggested by evidence, but by lack of evidence—an hypothesis which formulates absolute ignorance into a semblance of positive knowledge. Further, we see that this hypothesis, wholly without support, essentially inconceivable, and thus failing to satisfy men's intellectual need of an interpretation, fails also to satisfy their moral sentiment. It is quite inconsistent with those conceptions of the divine

CHAPTER III.

GENERAL ASPECTS OF THE EVOLUTION-HYPOTHESIS.

§ 116. JUST as the supposition that races of organisms have been specially created, is discredited by its origin; so, conversely, the supposition that races of organisms have been evolved, is credited by its origin. Instead of being a conception suggested and accepted when mankind were profoundly ignorant, it is a conception born in times of comparative enlightenment. Moreover, the belief that all organic forms have arisen in conformity with uniform laws, instead of through breaches of uniform laws, is a belief that has come into existence in the most-instructed class, living in these better-instructed times. Not among those who have paid no attention to the order of Nature, has this idea made its appearance; but among those whose pursuits have familiarized them with the order of Nature. Thus the derivation of this modern hypothesis is as favourable as that of the ancient hypothesis is unfavourable

§ 117. A kindred antithesis exists between the two families of beliefs, to which the beliefs we are comparing severally belong. While the one family has been dying out, the other family has been multiplying. Just as fast as men have ceased to regard different classes of phenomena as caused by special personal agents, acting irregularly; so fast have they come to regard these different classes of phenomena as caused by a general agency acting uniformly—the two changes being correlative. And as, on the one hand, the hypothesis that each species resulted from a supernatural act, having lost nearly all its kindred hypotheses, may be expected soon to become extinct; so, on the other hand, the hypothesis that each species resulted from the action of natural causes, being one of an ever-increasing family of hypotheses, may be expected to survive and become established.

Still greater will the probability of its survival and establishment appear, when we observe that it is one of a particular genus of hypotheses that has been rapidly extending. The interpretation of phenomena as resulting from Evolution, has been independently showing itself in various fields of inquiry, quite remote from one another. The supposition that the Solar System has been gradually evolved out of diffused matter, is a supposition wholly astronomical in its origin and application. Geologists, without being led thereto by astronomical considerations, have been step by step advancing towards the conviction, that the Earth has reached its present varied structure through a process of Evolution. The inquiries of biologists have proved the falsity of the once general belief, that the germ of each organism is a minute repetition of the mature organism, differing from it only in bulk; and they have shown, contrariwise, that every organism, arising out of apparently-uniform matter, advances to its ultimate multiformity through insensible changes. Among philosophical politicians, there has been spreading the perception that the progress of society is an evolution: the truth that "constitutions are not made but grow," is a part of the more general truth that societies are not made but grow. It is now universally admitted by philologists, that languages, instead of being artificially or supernaturally formed, have been developed. And the histories of religion, of philosophy, of science, of the fine arts, and of the industrial arts, show that these have passed through stages as unobtrusive as those through which the mind of a child passes on its way to maturity. If, then, the recognition of evolution as the law of many diverse orders of phenomena, has been spreading; may we not say that there thence arises the probability that evolution will presently be recognized as the law of the phenomena we are considering? Each further advance of knowledge, confirms the belief in the unity of Nature; and the discovery that evolution has gone on, or is going on, in so many departments of Nature, becomes a reason for believing that there is no department of Nature in which it does not go on.

§ 118. The hypotheses of Special Creation and Evolution, are no less contrasted in respect of their legitimacy as hypotheses. While, as we have seen, the one belongs to that order of symbolic conceptions which are proved to be illusive by the impossibility of realizing them in thought; the other is one of those symbolic conceptions which are more or less completely realizable in thought. The production of all organic forms by the slow accumulation of modifications upon modifications, and by the slow divergences resulting from the continual addition of differences to differences, is mentally representable in outline, if not in detail. Various orders of our experiences enable us to conceive the process. Let us look at one of the simplest.

There is no apparent similarity between a straight line and a circle. The one is a curve; the other is defined as without curvature. The one encloses a space; the other will not enclose a space though produced for ever. The one is finite; the other may be infinite. Yet, opposite as the two are in all their properties, they may be connected together by a series of lines no one of which differs from the adjacent ones in any appreciable degree. Thus, if a cone be cut by a plane at right angles to its axis, we get a circle. If, instead of being perfectly at right angles, the plane subtends with the axis an angle of 89° 59′, we have an ellipse which no human eye, even when aided by an accurate pair of compasses, can distinguish from a circle. Decreasing the angle minute

that a cyclopædia is needed to describe its constituent parts. The germinal vesicle is so simple that it may be defined in a line. Nevertheless, a few months suffice to develope the one out of the other; and that, too, by a series of modifications so small, that were the embryo examined at successive minutes, even a microscope would with difficulty disclose any sensible changes. Aided by such facts, the conception of general evolution may be rendered as definite a conception as any of our complex conceptions can be rendered. If instead of the successive minutes of a child's fœtal life, we take successive generations of creatures—if we regard the successive generations as differing from each other no more than the fœtus did in successive minutes; our imaginations must indeed be feeble if we fail to realize in thought, the evolution of the most complex organism out of the simplest. If a single cell, under appropriate conditions, becomes a man in the space of a few years; there can surely be no difficulty in understanding how, under appropriate conditions, a cell may, in the course of untold millions of years, give origin to the human race.

It is true that many minds are so unfurnished with those experiences of Nature out of which this conception is built, that they find difficulty in forming it. Habitually looking at things rather in their statical than in their dynamical aspects, they never realize the fact that, by small increments of modification, any amount of modification may in time be generated. That surprise which they feel on finding one whom they last saw as a boy, grown into a man, becomes incredulity when the degree of change is greater. To such, the hypothesis that by any series of changes a protozoon should ever give origin to a mammal, seems grotesque—as grotesque as did Galileo's assertion of the Earth's movement seem to the Aristotleans; or as grotesque as the assertion of the Earth's sphericity seems now to the New Zealanders. But those who accept a literally-unthinkable proposition as quite satisfactory, may not unnaturally be expected to make a converse mistake.

§ 119. The hypothesis of evolution is contrasted with the hypothesis of special creations, in a further respect. It is not simply legitimate instead of illegitimate, because representable in thought instead of unrepresentable; but it has the support of some evidence, instead of being absolutely unsupported by evidence. Though the facts at present assignable in *direct* proof that by progressive modifications, races of organisms that are apparently distinct may result from antecedent races, are not sufficient; yet there are numerous facts of the order required. It has been shown beyond all question that unlikenesses of structure gradually arise among descendants from the same stock. We find that there *is* going on a modifying process of the kind alleged as the source of specific differences: a process which, though slow in its action, does, in time, if the circumstances demand it, produce conspicuous changes—a process which, to all appearance, would produce in the millions of years, and under the great varieties of conditions which geological records imply, any amount of change.

In the chapters on "Heredity" and "Variation," contained in the preceding Part, many such facts were given; and plenty more might be added. Although comparatively little attention has been paid to the matter until recent times, the evidence already collected shows that there take place in successive generations, alterations of structure quite as marked as those which, in successive short intervals, arise in a developing embryo—nay, often much more marked; since, besides differences due to changes in the relative sizes of parts, there sometimes arise differences due to additions and suppressions of parts. The structural modification proved to have taken place since organisms have been observed, is not less than the hypothesis demands—bears as great a ratio to this brief period, as the total amount of structural change seen in the evolution of a complex organism out of a simple germ, bears to that vast period during which living forms have existed on the Earth.

We have, indeed, much the same kind and quantity of direct evidence that all organic beings have gradually arisen through the actions of natural causes, which we have that all the structural complexities of the Earth's crust have arisen through the actions of natural causes. It may, I think, be fairly said, that between the known modifications undergone by organisms, and the totality of modifications displayed in their structures, there is no greater disproportion than between the geological changes which have been witnessed, and the totality of geological changes supposed to be similarly caused. Here and there are pointed out sedimentary deposits now slowly taking place. At this place, it is proved that a shore has been encroached on by the sea to a considerable extent within recorded times; and at another place, an estuary is known to have become shallower within the space of some generations. In one region a general upheaval is going on at the rate of a few feet in a century; while in another region occasional earthquakes are shown to cause slight variations of level. Appreciable amounts of denudation by water are visible in some localities; and in other localities glaciers are detected in the act of grinding down the rocky surfaces over which they glide. But the changes thus instanced, are infinitesimal compared with the aggregate of changes to which the Earth's crust testifies, even in its still extant systems of strata. If, then, from the small changes now being wrought on the Earth's crust by natural agencies, we may legitimately conclude that by such natural agencies acting through vast epochs, all the structural complexities of the Earth's crust have been produced; may we not from the small known modifications produced in races of organisms by natural agencies, similarly infer that from natural agen-

records. But to the hypothesis of evolution, this absence is no such obstacle. Suppose evolution, and this question is necessarily excluded. Suppose special creations, and this question, unavoidably raised, can have no satisfactory answer. Still more marked is this contrast between the two hypotheses, in presence of that vast amount of suffering entailed on all orders of sentient beings, by their imperfect adaptations to their conditions of life; and the further vast amount of suffering entailed on them by enemies and by parasites. We saw that if organisms were severally designed for their respective places in Nature, the inevitable conclusion is, that these thousands of kinds of inferior organisms which prey upon superior organisms, were intended to inflict all the pain and mortality which results. But the hypothesis of evolution involves us in no such dilemma. Slowly, but surely, evolution brings about an increasing amount of happiness: all evils being but incidental. By its essential nature, the process must everywhere produce greater fitness to the conditions of existence; be they what they may. Applying alike to the lowest and the highest forms of organization, there is in all cases a progressive adaptation; and a survival of the most adapted. If, in the uniform working out of the process, there are evolved organisms of low types, which prey on those of higher types, the evils inflicted form but a deduction from the average benefits. The universal and necessary tendency towards supremacy and multiplication of the best, applying to the organic creation as a whole as well as to each species, is ever diminishing the damage done—tends ever to maintain those most superior organisms which, in one way or other, escape the invasions of the inferior, and so tends to produce a type less liable to the invasions of the inferior. Thus the evils accompanying evolution are ever being self-eliminated. Though there may arise the question—Why could they not have been avoided? there does not arise the question—Why were they deliberately inflicted? Whatever may be thought of them, it is clear that they do not imply gratuitous malevolence.

§ 121. In all respects, then, the hypothesis of evolution contrasts favourably with the hypothesis of special creation. It has arisen in comparatively-instructed times, and in the most cultivated class. It is one of those beliefs in the uniform concurrence of phenomena, which are gradually supplanting beliefs in their irregular and arbitrary concurrence; and it belongs to a genus of these beliefs which has of late been rapidly spreading. It is a definitely-conceivable hypothesis: being simply an extension to the organic world at large, of a conception built from our experiences of individual organisms; just as the hypothesis of universal gravitation, was an extension of the conception which our experiences of terrestrial gravitation had produced. This definitely-conceivable hypothesis, besides the support of numerous analogies, has the support of direct evidence: we have positive proof that there is going on a process of the kind alleged; and though the results of this process, as actually witnessed, are minute in comparison with the totality of results ascribed to it, yet they bear to such totality, a ratio as great as that by which an analogous hypothesis is justified. Lastly, that sentiment which the doctrine of special creations is thought necessary to satisfy, is much better satisfied by the doctrine of evolution; since this doctrine raises no contradictory implications respecting the Unknown Cause, such as are raised by the antagonist doctrine.

And now, having observed how, under its most general aspects, the hypothesis of evolution commends itself to us, by its derivation, by its coherence, by its analogies, by its direct evidence, by its implications; let us go on to consider the several orders of facts which yield indirect support to it. We will begin by noting the harmonies that exist between it, and sundry of the inductions set forth in Part II.

CHAPTER IV.

THE ARGUMENTS FROM CLASSIFICATION.

§ 122. In § 103, we saw that the relations which exist among the species, genera, orders, and classes of organisms, are not interpretable as results of any such causes as have been usually assigned. We will here consider whether they are interpretable as the results of evolution. Let us first contemplate some familiar facts.

The Norwegians, Swedes, Danes, Germans, Dutch, and Anglo-Saxons, form together a group of Scandinavian races, that are but slightly divergent in their characters. Welsh, Irish, and Highlanders, though they have differences, have not differences such as to hide a decided community of nature: they are classed together as Celts. Between the Scandinavian race as a whole and the Celtic race as a whole, there is a recognised distinction greater than that between the sub-divisions which make up one or the other. And the several peoples inhabiting Southern Europe are more nearly allied to one another, than the aggregate they form is allied to the aggregates of Northern peoples. If, again, we compare these European varieties of man taken as a group, with that group of Eastern varieties which had a common origin with it, we see a stronger contrast than between the European varieties themselves. And once more, ethnologists find differences of still higher importance, between the Aryan stock as a whole and the Mongolian stock as a whole,

well as Latin and Greek and certain extinct and spoken languages of the East, are shown to have traits in common, which, notwithstanding the wide gaps between them, unite them together as one great class of Aryan languages; radically distinguished from the classes of languages spoken by the other great divisions of the human race.

§ 123. Now this kind of subordination of groups, which we see arises in the course of continuous descent, multiplication, and divergence, is just the kind of subordination of groups which plants and animals exhibit: it is just this kind of subordination which has thrust itself on the attention of naturalists, in spite of pre-conceptions.

The original idea was that of arrangement in linear order. We saw that even after a considerable acquaintance with the structures of organisms had been acquired, naturalists continued their efforts to reconcile the facts with the notion of a uni-serial succession. The accumulation of evidence necessitated the breaking up of the imagined chain into groups and sub-groups. Gradually there arose the conviction that these groups do not admit of being placed in a line. And the conception finally arrived at, is, that of certain great sub-kingdoms, very widely divergent, each made up of classes much less widely divergent, severally containing orders still less divergent; and so on with genera and species. The diagram on page 303, shows the general relations of these divisions in their degrees of subordination.

Hence this "grand fact in natural history of the subordination of group under group, which from its familiarity does not always sufficiently strike us," is perfectly in harmony with the hypothesis of evolution. The extreme significance of this kind of relation among organic forms, is dwelt on by Mr Darwin; who shows how an ordinary genealogical tree represents, on a small scale, a system of grouping analogous to that which exists among organisms in general, and which is explained on the supposition of a genealogical tree by which all organisms are affiliated. If, wherever we can trace direct descent, multiplication, and divergence, this formation of groups within groups takes place; there results a strong presumption that the groups within groups which constitute the animal and vegetal kingdoms, have arisen by direct descent, multiplication, and divergence—that is, by evolution.

§ 124. Strong confirmation of this inference is furnished by the fact, that the more marked differences which divide groups, are, in both cases, distinguished from the less marked differences which divide sub-groups, by this, that they are not simply greater in *degree*, but they are more radical in *kind*. Objects, as the stars, may present themselves in small clusters, which are again more or less aggregated into clusters of clusters, in such manner that the individuals of each simple cluster, are much closer together than are the simple clusters composing a compound cluster: in which case, the kinship that unites groups of groups differs from the kinship that unites groups, not in *nature*, but only in *amount*. But this is not the case either with the groups and sub-groups which we know have resulted from evolution, or with those which we here infer have resulted from evolution. Among these, we find the highest or most general classes, are separated from one another by fundamental differences that have no common measure with the differences that separate small classes. Observe the parallelism.

We saw that each sub-kingdom of animals is marked off from the other sub-kingdoms, by a total unlikeness in its plan of organization: that is, the members of any sub-kingdom are bound together, not by some superficial attribute which they all have, but by some attribute determining the general nature of their organizations. While, contrariwise, the members of the smallest groups are united together, and separated from the members of other small groups, by modifications which do not affect the essential relations of parts. That this is just the kind of arrangement which results from evolution, the case of languages will show.

If we compare the dialects spoken in different parts of England, we find scarcely any differences but those of pronunciation: the structures of the sentences are almost uniform. Between English and the allied modern languages, there are decided divergences of structure: there are some unlikenesses of idiom; some unlikenesses in the ways of modifying the meanings of verbs; and considerable unlikenesses in the uses of genders. But these unlikenesses are not sufficient to hide a general community of organization. A greater contrast of structure exists between these modern languages of Western Europe, and the classic languages. That differentiation into abstract and concrete elements, which is shown by the substitution of auxiliary words for inflections, has produced a higher specialization distinguishing these languages as a group from the older languages. Nevertheless, both the ancient and modern languages of Europe, together with some Eastern languages derived from the same original, have, under all their differences of organization, a fundamental community of organization; inasmuch as all of them exhibit the formation of words by such a coalescence and integration of roots as destroys the independent meanings of the roots. These Aryan languages, and others which have the *amalgamate* character, are united by it into a class distinguished from the *aptotic* and *agglutinate* languages; in which the roots are either not united at all, or so incompletely united that one of them still retains its independent meaning. And philologists find that these fundamental differences which severally determine the grammatical forms, or modes of combining ideas, are really characteristic of the primary divisions among languages.

That is to say, among languages, where we know that evolution has been going on, the greatest groups are marked off from one another by the strongest structural contrasts; and as the like holds among groups of organisms, there re-

less distinct from German than Swedish is; while between the Danish and Swedish there is so close a kinship, that they might almost be regarded as widely-divergent dialects. Similarly on comparing the larger divisions, we see that the various languages of the Aryan stock, have deviated from the original to very unlike distances. The general conclusion is manifest. While the kinds of human speech fall into groups, and sub-groups, and sub-sub-groups; yet the groups are not equal to one another in value, nor have the sub-groups equal values, nor the sub-sub-groups.

If, then, the classification of organisms results in several orders of assemblages, such that assemblages of the same order are but indefinitely equivalent; and if, where evolution is known to have taken place, there have arisen assemblages between which the equivalence is similarly indefinite; there is additional reason for inferring that organisms are products of evolution.

§ 126. A fact of much significance remains. If groups of organic forms have arisen by divergence and re-divergence; and if, while the groups have been developing from simple groups into compound groups, each group and sub-group has been giving origin to more complex forms of its own type; then it is inferable that there once existed greater structural likenesses between the members of allied groups, than exist now. Hence, if we take the simplest members of any group to be those which have undergone the least change; we may expect to find a greater likeness between them and the simplest members of an allied group, than we find between the more complex members of the two groups. This, speaking generally, proves to be so.

Between the sub-kingdoms, the gaps are extremely wide; but such distant kinships as may be discerned, bear out anticipation. Speaking of that extremely-degraded vertebrate animal the *Amphioxus*, which has several molluscous traits in its organization, Dr Carpenter remarks, that it "furnishes an apt illustration of another important fact, that it is by the *lowest* rather than by the highest forms of two natural groups, that they are brought into closest relation." What are the faint traces of community between the *Annulosa* and the *Mollusca?* They are the thread-cells which some of their inferior groups have in common with the *Cœlenterata.* More decided approximations exist between the lower members of classes. In tracing down the *Crustacea* and the *Arachnida* from their more complex to their simpler forms, zoologists meet with difficulties: respecting some of these simpler forms, it becomes a question which class they belong to. The *Lepidosiren,* about which there have been disputes whether it is a fish or an amphibian, is inferior in the organization of its skeleton, to the great majority of both fishes and amphibia. Widely as they differ from them, the lower mammals have some characters in common with birds, which the higher mammals do not possess.

Now since this kind of relationship of groups is not accounted for by any other hypothesis, while the hypothesis of evolution gives us a clue to it; we must include it among the evidences of this hypothesis, which the facts of classification furnish.

§ 127. What shall we say of these several leading truths when taken together? That naturalists have been gradually compelled to arrange organisms in groups within groups; and that this is the arrangement which we see arises by descent, alike in individual families and among races of men, is a striking circumstance. That while the smallest groups are the most nearly related, there exist beween the great sub-kingdoms, structural contrasts of the profoundest kind; cannot but impress us as remarkable, when we see that where it is known to take place, evolution actually produces these feebly-distinguished small groups, and these strongly-distinguished great groups. The impression made by these two parallelisms, which add meaning to each other, is deepened by the third parallelism, which enforces the meaning of both —the parallelism, namely, that as, between the species, genera, orders, classes, &c., which naturalists have formed, there are transitional gradations; so between the groups, sub-groups, and sub-sub-groups, which we know to have been evolved, groups of intermediate values exist. And these three correspondences between the known results of evolution, and the results here ascribed to evolution, have further weight given to them by the circumstance, that the kinship of groups through their lowest members, is just the kinship which the hypothesis of evolution implies.

Even in the absence of these specific agreements, the broad fact of unity amid multiformity, which organisms so strikingly display, is strongly suggestive of evolution. Freeing ourselves from pre-conceptions, we shall see good reason to think with Mr Darwin, "that propinquity of descent—the only known cause of the similarity of organic beings—is the bond, hidden as it is by various degrees of modification, which is partly revealed to us by our classifications." When we consider that this only known cause of similarity, joined with the only known cause of divergence, which we have in the influence of conditions, gives us a key to those likenesses obscured by unlikenesses, to which no consistent interpretation can otherwise be given, even if purely hypothetical causes be admitted; we shall see that were there none of those very remarkable harmonies above pointed out, the truths of classification would still yield strong support to our conclusion.

branches; we shall see that there must result an aggregate analogous, in its arrangement of parts, to a tree. If this vast genealogical tree be contemplated as a whole, made up of trunk, great branches, secondary branches, and so on, as far as the terminal twigs; it will be perceived that all the various kinds of organisms represented by these terminal twigs, forming the periphery of the tree, will stand related to each other in small groups, which are united into groups of groups, and so on. The embryological tree, expressing the developmental relations of organisms, will be similar to the tree which symbolizes their classificatory relations. That subordination of classes, orders, genera, and species, to which naturalists have been gradually led, is just that subordination which results from the divergence and re-divergence of embryos, as they all unfold. On the hypothesis of evolution, this parallelism has a meaning—indicates that primordial kinship of all organisms, and that progressive differentiation of them, which the hypothesis alleges. But on any other hypothesis the parallelism is meaningless: or rather, it raises a difficulty; since it implies either an effect without a cause, or a design without a purpose.

§ 129. It was said above, that this great embryological law is to be taken with certain qualifications. The resemblances which hold together great groups of embryos in their early stages, and which hold together smaller and smaller groups in their later and later stages, are not special or exact, but general or approximate; and in some cases, the conformity to this general law is very imperfect. These irregularities, however, instead of being at variance with the hypothesis of evolution, afford further support to it.

Observe, first, that the only two other possible suppositions respecting developmental changes, are negatived, the one by this general law and the other by the minor nonconformities to it. If it be said that the conditions of the case necessitated the derivation of all organisms from simple germs, and therefore necessitated a morphological unity in their primitive states; there arises the obvious answer, that the morphological unity thus implied, is not the only morphological unity to be accounted for. Were this the only unity, the various kinds of organisms, setting out from a common primordial form, should all begin from the first to diverge individually, as so many radii from a centre; which they do not. If, otherwise, it be said that organisms were framed upon certain types, and that those of the same type continue developing together in the same direction, until it is time for them to begin putting on their specialities of structure; then, the answer is, that when they do finally diverge, they ought severally to develop in direct lines towards their final forms. No reason can be assigned why, having once parted company, some should progress towards their final forms by irregular or circuitous routes. On the hypothesis of design, such deviations are inexplicable.

The hypothesis of evolution, however, while it pre-supposes those general relations among embryos which are found to exist, also affords explanations of these minor nonconformities. If, as any rational theory of evolution pre-supposes, the progressive differentiations of organic forms from one another during past times, have resulted, as they are resulting still, from the direct and indirect effects of external conditions—if organisms have become different, either by immediate adaptations to unlike habits of life, or by the mediate adaptations resulting from preservation of the individuals most fitted for such habits of life, or by both; and if the embryonic changes are related to the changes that were undergone by ancestral races; then these irregularities must be expected. For the successive changes in modes of life pursued by successive ancestral races, can have had no regularity of sequence. In some cases they must have been more numerous than in others; in some cases they must have been greater in degree than in others; in some cases they must have been to lower modes, in some cases to higher modes, and in some cases to modes neither higher nor lower. Of two connate races which diverged in the remote past, the one may have had descendants that have remained tolerably constant in their habits, while the other may have had descendants that have passed through widely-aberrant modes of life; and yet some of these last may have eventually taken to modes of life like those of the divergent races derived from the same stock. And if the metamorphoses of embryos, indicate, in a general way, the changes of structure undergone by ancestors; then, the later embryologic changes of such two allied races, will be somewhat different, though they may end in very similar forms. An illustration will make this clear. Mr Darwin says:—"Petrels are the most aërial and oceanic of birds, but in the quiet sounds of Tierra del Fuego, the *Puffinuria berardi*, in its general habits, in its astonishing power of diving, its manner of swimming, and of flying when unwillingly it takes flight, would be mistaken by any one for an auk or grebe; nevertheless, it is essentially a petrel, but with many parts of its organization profoundly modified." Now if we suppose these grebe-like habits to be continued through a long epoch, the petrel-form to be still more obscured, and the approximation to the grebe-form still closer; it is manifest that while the chicks of the grebe and the *Puffinuria* will, during their early stages of development, display that likeness involved by their common derivation from some early type of bird, the chick of the *Puffinuria* will eventually begin to show deviations, representative of the ancestral petrel-structure, and will afterwards begin to lose these distinctions, and assume the grebe-structure.

Hence, remembering the perpetual intrusions of organisms on one another's modes of life, often widely different; and remembering that these intrusions have been going on from the beginning; we shall be prepared to find that the general law of embryologic parallelism, is qualified by irregularities that are mostly small, in many cases considerable, and

the second system of external blood-vessels is, to the implacental embryo, of no greater avail than the first; and since the communication between the embryo and the placenta among placental mammals, might as well or better have been made directly, instead of by metamorphosis of the allantois; these substitutions appear unaccountable as results of design. But they are quite congruous with the supposition, that the mammalian type arose out of lower vertebrate types. For in such case, the mammalian embryo, passing through states representing, more or less distinctly, those which its remote ancestors had in common with the lower *Vertebrata*, develops these subsidiary organs in like ways with the lower *Vertebrata*.

Even more striking than the substitutions of organs are the suppressions of organs. Mr Darwin names some cases as "extremely curious; for instance, the presence of teeth in fœtal whales, which when grown up have not a tooth in their heads; * * * It has even been stated on good authority that rudiments of teeth can be detected in the beaks of certain embryonic birds." Not even temporary functions can be assigned for these organs that are first built up and then pulled down again. They are absolutely useless—their formation is absolutely superfluous. Irreconcilable with any teleological theory, they do not even harmonize with the theory of fixed types which are maintained by the development of all the typical parts, even where not wanted; seeing that the disappearance of these incipient organs during fœtal life, spoils the typical resemblance. But while to all other hypotheses these facts are stumbling-blocks, they yield strong support to the hypothesis of evolution.

Allied to these cases, are the cases of what has been called retrograde development. Many parasitic creatures and creatures which, after leading active lives for a time, eventually become fixed, lose, in their adult states, the limbs and senses which they had when young. It may be alleged however, that these creatures could not secure the habitats needful for them, without possessing during their larval stages, eyes and swimming appendages which eventually become useless; that though, by losing these, their organization retrogresses in one direction, it progresses in another direction; and that, therefore, they do not exhibit the needless development of a higher type on the way to a lower type. Nevertheless there are instances of a descent in organization, following an apparently-superfluous ascent. Mr Darwin says that in some genera of cirripedes, "the larvæ become developed either into hermaphrodites having the ordinary structure, or into what I have called complemental males, and in the latter, the development has assuredly been retrograde; for the male is a mere sack, which lives for a short time, and is destitute of mouth, stomach, or other organ of importance, excepting for reproduction."

§ 131. Comparative embryology shows us that besides substitutions of organs, there are what may be called substituted modes of development. The same kind of structure is not always produced in the same way; and some allied groups of organisms have modes of evolution which appear to be radically contrasted. The two modes are broadly distinguishable as the *direct* and the *indirect*. They may severally characterize the general course of evolution as a whole, and the course of evolution in particular organs.

Thus in the immense majority of articulate animals, metamorphoses, more or less marked and more or less numerous, are passed through on the way to maturity. The familiar transformations of insects show us how circuitous is the route by which the embryo-form arrives at the adult form, among some divisions of the *Articulata*. But there are other divisions, as the lower *Arachnida*, in which the unfolding of the egg into the adult takes place in the simplest manner: the substance grows towards its appointed shape by the shortest route. The *Mollusca* furnish contrasts which, though less marked, are essentially of the same nature. Among some Gasteropods, according to Vogt, the germ-mass, after undergoing its earliest changes in the same way as germ-masses in general, begins to transform itself bodily into the finished structure: in one part, the component cells coalesce to form the heart, in another part to form the liver, and so on. But in other classes of molluscs, as the Cephalopods, the embryo is moulded out of the blastoderm, or superficial layer of the germ-mass; and the various organs, mostly arising out of this blastoderm by a process of budding, reach their ultimate shapes through successive modifications, while they grow at the expense of the nutriment absorbed from the rest of the germ-mass. And this indirect development is universal among the *Vertebrata*.

Now on contemplating in their *ensemble*, the facts thus briefly indicated, we may trace among these irregularities something like a general rule. The indirect development characterizes the most-highly-organized forms. In the sub-kingdom *Vertebrata*, which, considered as a whole, stands far above the rest in complexity, the development is uniformly indirect. It is indirect in the great mass of the *Articulata*. It is indirect in the highest *Mollusca*. Conversely, it is direct in a large proportion of the lower types. The eggs of *Protozoa*, of *Cœlenterata*, of inferior *Annuloida*, originate the respective structures proper to them, by transformations that are almost immediate; each of the cycle of forms passed through, is assumed, when the proper time comes, in the simplest way; and where they multiply by budding, the substance of the bud passes by as short a process as may be, into the finished form. Where among the simpler types of animals, the evolution is indirect, its indirectness generally appears to be related to some transitional mode of life, which the larva passes through on its way to maturity; and where we find direct evolution among the more complex types, it is

when there grow up in one place, as a Manchester or a Birmingham, many establishments of like kind, this process is carried still further. There arise factors and agents, who are the channels through which are transmitted the produce of many mills; and we believe that primarily, these factors were manufacturers who undertook to dispose of the produce of smaller houses as well as their own, and ultimately became salesmen only. Now this, which is the original mode in which social agencies of all kinds are evolved, does not continue to be the mode. There is a tendency everywhere manifested to substitute a direct process for this indirect process. Manufacturing establishments are no longer commonly developed through the series of modifications above described; but mostly arise by the immediate transformation of a number of persons into master, clerks, foremen, workers, &c. Instead of business-partnerships being formed, as they originally were, by some slow unobtrusive union between traders and their sons or assistants; we now have joint-stock-companies resulting by sudden metamorphoses of groups of citizens. The like is true with larger and more complex social agencies. A new town in the United States arises not at all after the old method of gradual accumulations round a nucleus, and successive small modifications of structure accompanying increase of size; but it grows up over a large area, according to a pre-determined plan; and there are developed at the outset, those various civil, ecclesiastical, and industrial centres, which the incipient city will require. Even in the formation of colonies we may similarly see, that the whole type of social organization proper to the race from which the colony comes, begins at once to show itself. There is not a gradual passing through all those developmental phases passed through by the mother-society; but there is a comparatively direct transformation of the assemblage of colonists, into a social organism allied in structure to the social organism of which it was an offset.

Let us now return to the development of individual organisms; carrying back this idea with us. On the hypothesis of evolution. all organs must have been originally formed after the indirect method, by the accumulation of modifications upon modifications; and if the development of the embryo repeats the development of ancestral races, organs must be thus formed in the embryo. To a considerable extent they are thus formed. There is a striking parallelism between the mode in which, as above described, manufacturing agencies are originally evolved, and the mode in which secreting organs are evolved. Out of the group of bile-cells forming the germ of the liver, some centrally-placed ones, lying next to the intestine, are transformed into ducts through which the secretion of the peripheral bile-cells is poured into the intestine; and as the peripheral bile-cells multiply, there similarly arise secondary ducts emptying themselves into the main ones; tertiary ones into these; and so on. But while in this and in other organs, the development remains in a great degree indirect; there are organs, as the heart, in which it is comparatively direct. The heart of the vertebrate embryo does not arise from a bud; but it is first traceable as an aggregated mass of cells, becoming distinct from the cells amid which it is imbedded: its transformation into a contractile chamber, is effected by the consolidation of its outer cells while its inner cells liquify. And the comparatively direct development thus displayed in some organs of the higher embryos, is, as we have seen, characteristic of the entire development in many lower embryos.

On the hypothesis of evolution, the direct mode of development in animals, must have been substituted for the indirect mode; as we see that it is substituted in societies. How comes it to have been substituted? By studying the cause of the substitution in the social organism, we may perhaps get some insight into its cause in the individual organism. The direct mode of forming social agencies replaces the indirect mode, when these social agencies have either been so long established, or have become so prevalent, or both, as to modify the people's habits and ideas. Groups of citizens unite into corporate bodies which quickly organize, because the habit of forming such combinations has so far modified the thoughts and feelings of citizens, that it becomes natural to them thus to arrange themselves. So too, is it with the men who form a colony. The rapid assumption by them of a social structure, as similar as circumstances permit to the structure of the mother-society, is manifestly due to the fact, that the organization of the mother-society has moulded the emotions and beliefs of its members into conformity with itself; so that when some of its members are transferred to a colony, they arrange themselves directly into a structure of like type with that of the mother-society: they do not repeat all the stages through which the mother-society passed, because their natures have been too far modified to allow of their doing this. That action and reaction between a social organism and its units, which we here see accounts for changes in modes of social development, must be paralleled by the action and reaction between an individual organism and its units. Various classes of phenomena compelled us to conclude, that each kind of organism is composed of physiological units, having certain peculiarites which force them to arrange themselves into the form of the species to which they are peculiar. And in the chapters on Genesis, Heredity, and Variation, we saw reason to believe, that while the polarities of the physiological units determine the structure of the organism as a whole; the organism as a whole, if its structure is changed by incident forces, reacts on the physiological units, and modifies them towards conformity with its new structure. Now this action and reaction between an organic aggregate and its units, tending ever to bring the two into absolute harmony, must be continually making the developmental processes more direct;

great indirectness, are the organs of external relation; which, in the progress of organic forms, undergo various metamorphoses. Some light, too, is thus thrown on certain irregularities in the *order* of development of organs. If we contemplate those continuous actions and reactions which tend ever to establish a balance between an organic aggregate and its units; we shall see that the effect which the units composing any organ, produce on the organism as a whole, will depend, partly on the *permanence* of such organ, and partly on its proportional *mass*. The influence of any force, is a product of its *amount* multiplied into the *time* during which it has acted. Hence, a larger part of the aggregate acting for a shorter time, will impress itself on the physiological units, as much as a smaller part acting for a longer time; and may thus begin to show its influence in the developmental changes, as soon as, or even earlier than, a part that has existed for a greater period. Thus it becomes comprehensible why, in certain *Entozoa* which have immensely-developed generative systems, the rudiments of the generative systems are the first to become visible. And thus are also explicable, anomalies such as those pointed out by Prof. Agassiz—the appearance, in some cases, of traits characterizing the species, at an earlier period of development than traits characterizing the genus.

§ 132. So that while the embryologic law enunciated by Von Baer, is in harmony with the hypothesis of evolution, and is, indeed, a law which this hypothesis implies; the minor nonconformities to the law, are also interpretable by this hypothesis. Parallelism between the courses of development in species that had a common ancestry, is liable to be variously modified in correspondence with the later ancestral forms passed through after divergence of such species. The substitution of a direct for an indirect process of formation, which we have reason to believe will show itself, both in the unfolding of the entire organism and in the unfolding of particular organs, must obscure the embryologic history. And the parts influencing the whole in degrees varying with their masses, there results a further influence which, from the outset, must begin to modify the metamorphoses of each kind of embryo; and cause it to show incipient divergences from embryos which had ancestral histories the same as its own. Thus we find three different causes conspiring in endless ways and degrees, to produce deviations from the general law —causes which are manifestly capable of producing, under special conditions, changes in apparent contradiction to this law.

CHAPTER VI.

THE ARGUMENTS FROM MORPHOLOGY.

§ 133. Leaving out of consideration the parallelism of development which characterizes organisms belonging to each group, that community of plan which exists among them when they are mature, is extremely remarkable and extremely suggestive. As before shown (§ 103), neither the supposition that these combinations of attributes which unite classes are fortuitous, nor the supposition that no other combinations were practicable, nor the supposition of adherence to predetermined typical plans, suffices to explain the facts. An instance will best prepare the reader for seeing the true meaning of these fundamental likenesses.

Under the immensely-varied forms of insects, greatly elongated like the dragon-fly, or contracted in shape like the lady-bird, winged like the butterfly, or wingless like the flea, we find this character in common—there are primarily twenty segments. These segments may be distinctly marked, or they may be so fused as to make it difficult to find the divisions between them. This is not all. It has been shown that the same number of segments is possessed by all the *Crustacea*. The highly-consolidated crab, and the squilla with its long, loosely-jointed divisions, are composed of the same number of somites. Though, in the higher crustaceans, some of these successive indurated rings, forming the exo-skeleton, are never more than partially marked off from each

as the superposed modifications of structure, have or have not been great or long maintained. Hence, though the occurrence of articulate animals, such as spiders and mites, having fewer than twenty segments, is fatal to the supposition that twenty segments was decided on for the three groups of superior *Articulata;* it is not incongruous with the supposition, that some primitive race of articulate animals, bequeathed to these three groups this common typical character—a character which has nevertheless, in many cases, become greatly obscured, and in some of the most aberrant orders of these classes, quite lost.

§ 134. Besides these wide-embracing and often deeply-hidden homologies, which hold together different animals, there are the scarcely-less significant homologies between different organs of the same animal. These homologies, like the others, are obstacles to the supernatural interpretations, and supports of the natural interpretation.

One of the most familiar and instructive instances is furnished by the vertebral column. Snakes, which move sinuously through and over plants and stones, obviously need a segmentation of the bony axis from end to end; and inasmuch as flexibility is required throughout the whole length of the body, there is advantage in the comparative uniformity of this segmentation: the creature's movements would be impeded if, instead of a chain of vertebræ varying but little in their lengths, there existed in the middle of the series some long bony mass that would not bend. But in most of the higher *Vertebrata*, the mechanical actions and reactions demand that while some parts of the vertebral axis shall be flexible, other parts shall be inflexible. Inflexibility is especially requisite in that part of the vertebral column called the sacrum; which, in mammals and birds, forms a fulcrum exposed to the greatest strains which the skeleton has to bear. Now in both mammals and birds, this rigid portion of the vertebral column is not made of one long segment or vertebra, but of several segments fused together. In man there are five of these confluent sacral vertebræ; and in the ostrich tribe they number from seventeen to twenty. Why is this? Why, if the skeleton of each species was separately contrived, was this bony mass made by soldering together a number of vertebræ like those forming the rest of the column, instead of being made out of one simple piece? And why, if typical uniformity was to be maintained, does the number of sacral vertebræ vary within the same order of birds? Why, too, should the development of the sacrum be by the round-about process of first forming its separate constituent vertebræ, and then destroying their separateness? In the embryo of a mammal or bird, the substance of the vertebral column is, at the outset, continuous. The segments that are to become vertebræ, arise gradually in the midst of this originally-homogeneous axis. Equally in those parts of the spine which are to remain flexible, and in those parts which are to grow rigid, these segments are formed; and that part of the spine which is to compose the sacrum, having passed out of its original unity into disunity, by separating itself into segments, passes again into unity by the coalescence of these segments. To what end is this construction and re-construction? If, originally, the spine in vertebrate animals consisted from head to tail of separate moveable segments, as it does still in fishes and some reptiles—if, in the evolution of the higher *Vertebrata*, certain of these moveable segments were rendered less moveable with respect to each other, by the mechanical conditions to which they are exposed, and at length became relatively immoveable; it is comprehensible why the sacrum formed out of them, should continue ever after to show more or less clearly its originally-segmented structure. But on any other hypothesis, this segmented structure is inexplicable. "We see the same law in comparing the wonderfully complex jaws and legs in crustaceans," says Mr Darwin: referring to the well-known fact that those numerous lateral appendages which, in the lower crustaceans most of them serve as legs, and have like shapes, are, in the higher crustaceans, some of them represented by enormously-developed claws, and others by variously-modified foot-jaws. "It is familiar to almost every one," he continues, "that in a flower the relative position of the sepals, petals, stamens, and pistils, as well as their intimate structure, are intelligible on the view that they consist of metamorphosed leaves arranged in a spire. In monstrous plants we often get direct evidence of the possibility of one organ being transformed into another; and we can actually see in embryonic crustaceans and in many other animals, and in flowers, that organs, which when mature become extremely different, are at an early stage of growth exactly alike." • • • "Why should one crustacean, which has an extremely complex mouth formed of many parts, consequently always have fewer legs; or conversely, those with many legs have simpler mouths? Why should the sepals, petals, stamens, and pistils in any individual flower, though fitted for such widely-different purposes, be all constructed on the same pattern?"

To these and countless similar questions, the theory of evolution furnishes the only rational answer. In the course of that change from homogeneity to heterogeneity of structure, displayed in evolution under every form, it will necessarily happen that from organisms made up of numerous like parts, there will arise organisms made up of parts more and more unlike: which unlike parts will nevertheless continue to bear traces of their primitive likeness.

§ 135. One more striking morphological fact, near akin to some of the facts dwelt on in the last chapter, must be here set down—the frequent occurrence, in adult animals and plants, of rudimentary and useless organs, which are homologous with organs that are developed and useful in allied animals and plants. In the last chapter we saw that

bearing fibres, each of which again bears a fringe of down. But in some birds, as in the ostrich, various stages of arrested development of the feathers may be traced; beginning with the unusually-elaborated feathers of the tail, and ending with those about the beak, which are reduced to simple hairs. Nor is this the extreme case. In the *Apteryx* we see the whole of the feathers reduced to a hair-like form. Again, the hair which commonly covers the body in mammals, is comparatively rudimentary over the greater part of the human body, and is in some parts reduced to mere down—down which nevertheless proves itself to be homologous with the hair of mammals in general, by occasionally developing into the original form. Numerous cases of aborted organs are given by Mr Darwin, of which a few may be here added. "Nothing can be plainer," he remarks, "than that wings are formed for flight, yet in how many insects do we see wings so reduced in size as to be utterly incapable of flight, and not rarely lying under wing-cases, firmly soldered together?" • • • "In plants with separated sexes, the male flowers often have a rudiment of a pistil; and Kölreuter found that by crossing such male plants with an hermaphrodite species, the rudiment of the pistil in the hybrid offspring was much increased in size; and this shows that the rudiment and the perfect pistil are essentially alike in nature." And then, to complete the proof that these undeveloped parts are marks of descent from races in which they were developed, there are not a few direct experiences of this relation. "We have plenty of cases of rudimentary organs in our domestic productions—as the stump of a tail in tailless breeds—the vestige of an ear in earless breeds—the re-appearance of minute dangling horns in hornless breeds of cattle."

Here, as before, the teleological doctrine fails utterly; for these rudimentary organs are useless, and occasionally even detrimental. The doctrine of typical plans is equally out of court; for while, in some members of a group, rudimentary organs completing the general type are traceable,

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in other members of the same group, such organs are unrepresented. There remains only the doctrine of evolution; and to this, these rudimentary organs offer no difficulties. On the contrary, they are among its most striking evidences.

§ 136. The general truths of morphology thus coincide in their implications. Unity of type, maintained under extreme dissimilarities of form and mode of life, is explicable as resulting from descent with modification; but is otherwise inexplicable. The likenesses disguised by unlikenesses, which the comparative anatomist discovers between various organs in the same organism, are worse than meaningless if it be supposed that organisms were severally framed as we now see them; but they fit in quite harmoniously with the belief, that each kind of organism is a product of accumulated modifications upon modifications. And the presence in all kinds of animals and plants, of functionally-useless parts corresponding to parts that are functionally-useful in allied animals and plants, while it is totally incongruous with the belief in a construction of each organism by miraculous interposition, is just what we are led to expect by the belief that organisms have arisen by progression.

CHAPTER VII.

THE ARGUMENTS FROM DISTRIBUTION.

§ 137. In §§ 105 and 106, we contemplated the phenomena of distribution in Space. The general conclusions reached, in great part based on the evidence brought together by Mr Darwin, were that, "on the one hand, we have similarly-conditioned, and sometimes nearly-adjacent, areas, occupied by quite different Faunas. On the other hand, we have areas remote from each other in latitude, and contrasted in soil as well as climate, which are occupied by closely-allied Faunas." Whence it was inferred that "as like organisms are not universally, or even generally, found in like habitats; nor very unlike organisms, in very unlike habitats; there is no manifest pre-determined adaptation of the organisms to the habitats." In other words, the facts of distribution in Space, do not conform to the hypothesis of design. At the same time we saw that "the similar areas peopled by dissimilar forms, are those between which there are impassable barriers; while the dissimilar areas peopled by similar forms, are those between which there are no such barriers;" and these generalizations appeared to be in harmony with the abundantly-illustrated truth, "that each species of organism tends ever to expand its sphere of existence—to intrude on other areas, other modes of life, other media."

By way of showing still more clearly the effects of this competition among races of organisms, let me here add some recently-published instances of the usurpations of areas, and

actions before experienced. Now if changes of organic structure are caused, directly or indirectly, by changes in the incidence of forces; there must result unlikenesses of structure between the divisions of a race which colonizes new habitats. Hence, in the absence of obstacles to migration, we may anticipate manifest kinships between the animals and plants of one area, and those of areas adjoining it. This inference corresponds with an induction before set down (§ 106). In addition to the illustrations of it already quoted from Mr Darwin, his pages furnish others. One is that species which inhabit islands are habitually allied to species which inhabit neighbouring main lands; and another is that the faunas of clustered islands show marked similarities. "Thus the several islands of the Galapagos Archipelago are tenanted," says Mr Darwin, "in a quite marvellous manner, by very closely related species; so that the inhabitants of each separate island, though mostly distinct, are related in an incomparably closer degree to each other than to the inhabitants of any other part of the world." Mr Wallace has traced "variation as specially influenced by locality" among the *Papilionidæ* inhabiting the East Indian Archipelago: showing how "the species and varieties of Celebes possess a striking character in the form of the anterior wings, different from that of the allied species and varieties of all the surrounding islands;" and how "tailed species in India and the western islands lose their tails as they spread eastward through the archipelago." During his travels on the Upper Amazons, Mr Bates found that "the greater part of the species of *Ithomia* changed from one locality to another, not further removed than 100 to 200 miles;" that "many of these local species have the appearance of being geographical varieties;" and that in some species "most of the local varieties are connected with their parent form by individuals exhibiting all the shades of variation."

Further general relationships are to be inferred. If races of organisms, ever being thrust by pressure of population into new habitats, undergo modifications of structure as they diverge more and more widely in space, it follows that, speaking generally, the widest divergences in Space will indicate the longest periods during which the descendants from a common stock have been subject to modifying conditions; and hence that, among organisms of the same group, the smaller constrasts of structure will be limited to the smaller areas. This we find: "varieties being," as Dr Hooker says in his *Flora of Tasmania*, "more restricted in locality than species, and these again than genera." Again, if races of organisms spread, and as they spread are altered by changing incident forces; it follows that where the incident forces vary greatly within given areas, the alterations will be more numerous than in equal areas which are less-variously conditioned. This, too, proves to be the fact. Dr Hooker points out that the most uniform regions have the fewest species; while in the most multiform regions the species are the most numerous.

§ 139. Let us consider next, how the hypothesis of evolution corresponds with the facts of distribution, not over different areas, but through different media. If all forms of organisms have descended from some primordial simplest form, it follows that, since this primordial simplest form must have inhabited some one medium out of the several media which organisms now inhabit, the peopling of other media by its descendants, implies migration from one medium to others—implies adaptations to media quite unlike the original medium. To speak specifically—water being the medium in which the lowest living forms exist, it is implied that the earth and the air have been colonized from the water. Great difficulties appear to stand in the way of this assumption. Ridiculing those who contend for the uniserial development of organic forms, who have, indeed, laid themselves open to ridicule by their many untenable propositions, Von Baer writes—"A fish, swimming towards the shore, desires to take a walk, but finds his fins useless. They diminish in breadth for want of use, and at the same time elongate. This goes on with children and grandchildren for a few millions of years, and at last who can be astonished that the fins become feet? It is still more natural that the fish in the meadow, finding no water, should gape after air, thereby, in a like period of time developing lungs; the only difficulty being that in the meanwhile, a few generations must manage without breathing at all." Though, as thus presented, the belief in a transition looks laughable; and though such derivation of terrestrial vertebrates by direct modification of the piscine type, is untenable; yet we must not therefore conclude that no migrations of the kind alleged can have taken place. The adage that "truth is stranger than fiction," applies quite as much to Nature in general as to human life. Besides the fact that there are certain fish which actually do "take a walk" without any very obvious reason; and besides the fact that sundry fish ramble about on land when impelled to do so by the drying-up of the waters inhabited by them; there is the still more astounding fact, that one kind of fish climbs trees. Few things seem more obviously impossible, than that a water-breathing creature without efficient limbs should ascend eight or ten feet up the trunk of a palm; and yet the *Anabas scandens* does as much. To previous testimonies on this point, Capt. Mitchell has recently added others. Such remarkable cases of temporary changes of media, will prepare us for conceiving how, under special conditions, permanent changes of media may have taken place; and for considering how the doctrine of evolution is elucidated by them.

Both marine organisms and fresh-water organisms, are many of them left from time to time partially or completely without water; and the creatures which show the power to change their media temporarily or permanently, are in very

crustaceans have their species which live occasionally, or almost entirely, out of the water: there is a kind of lobster in the Mauritius which climbs trees; and there is the land-crab of the West Indies, which deserts the sea when it reaches maturity, and re-visits it only to spawn. Seeing, thus, how there are many kinds of marine creatures whose habitat habitually exposes them to changes of media; how some of the higher kinds so circumstanced, show a considerable adaptation to both media; and how these amphibious kinds are allied to kinds that are mainly or wholly terrestrial; we shall see that the migrations from one medium to another, which evolution pre-supposes, are by no means impracticable. With such evidence before us, the assumption that the distribution of the *Vertebrata* through media so different as air and water, may have been gradually effected in some analogous manner, would not be altogether unwarranted, even had we no clue to the process. We shall find, however, a tolerably distinct clue. Though rivers, and lakes, and pools, have no sensible tidal variations, they have their rises and falls, regular and irregular, moderate and extreme. Especially in tropical climates, we see them annually full for a certain number of months, and then dwindling away and drying up. This drying up may reach various degrees, and last for various periods: it may go to the extent only of producing a liquid mud, or it may reduce the mud to a hardened, fissured solid; it may last for a day or two or for months. That is to say, aquatic forms which are in one place annually subject to a slight want of water for a short time, are elsewhere subject to greater wants for longer times: we have gradations of transition, analogous to those which the tides furnish. Now it is well known that creatures inhabiting such waters, have, in various degrees, powers of meeting these contingences. The contained fish either bury themselves in the mud when the dry season comes, or ramble in search of other waters. This is proved by evidence from India, Guiana, Siam, Ceylon; and some of these fish, as the *Anabas scandens*, are

to the water now and then. Finally, if we ask under what conditions this metamorphosis of a water-breather into an air-breather completes itself, the answer is—it completes itself at the time when the shallow pools inhabited by the larvæ, are being dried up by the summer's sun.*

See, then, how significant are the facts when thus brought together. There are particular habitats in which animals are subject to changes of media. In such habitats exist animals having, in various degrees, the power to live in both media, consequent on various phases of transitional organization. Near akin to these animals, there are some that, after passing their early lives in the water, acquire more completely the structures fitting them to live on land, to which they then migrate. Lastly, we have closely-allied creatures like the Surinam toad and the terrestrial salamander, which, though they belong by their structures to the class *Amphibia*, are not amphibious in their habits—creatures the larvæ of which do not pass their early lives in the water, and yet go through these same metamorphoses! Must we then think that the distribution of kindred organisms through different media, presents an insurmountable difficulty? On the contrary, with facts like these before us, the evolution-hypothesis supplies possible interpretations of many phenomena that are else unaccountable. Realizing the way in which such changes of media are in some cases gradually imposed by physical conditions, and in other cases voluntarily commenced and slowly increased in the search after food; we shall begin to understand how, in the course of evolution, there have arisen

* While these pages are passing through the press, Dr Hooker has obliged me by pointing out, that "plants afford many excellent examples" of analogous transitions. He says that among true "water plants," there are found, in the same species, varieties which have some leaves submerged and some floating; other varieties in which they are all floating; and other varieties in which they are all submerged. Further, that many plants characterized by floating leaves, and which have all their leaves floating when they grow in deeper water, are found with partly aerial leaves when they grow in shallower water; and that elsewhere they occur in almost dry soil with all their leaves aerial.

weight than any other evidence. As it is, all we can do is to see whether such fragmentary evidence as remains, is congruous with the hypothesis.

Palæontology has shown that there is a "general relation between lapse of time and divergence of organic forms" (§ 107); and that "this divergence is comparatively slow and continuous, where there is continuity in the geological formations, but is sudden and comparatively wide, wherever there occurs a great break in the succession of strata." Now this is obviously what we should expect. The hypothesis implies structural changes that are not sudden but gradual. Hence, where conformable strata indicate a continuous record, we may expect to find successions of forms only slightly different from one another; while we may rationally look for considerable contrasts between the groups of forms fossilised in adjacent strata, where there is evidence of a great blank in the record.

The permanent disappearances of species, of genera, and of orders, which we saw to be a fact tolerably-well established, is also a fact for which the belief in evolution prepares us. If later organic forms have in all cases descended from earlier organic forms, and have diverged during their descent, both from their prototypes and from one another; then it obviously follows, that such of them as become extinct at any epoch, will never re-appear at a subsequent epoch; since there can never again arise a concurrence and succession of conditions, such as those under which each particular type was evolved.

Though comparisons of ancient and modern organic forms, prove that many types have persisted through enormous periods of time, without undergoing great changes; it was shown that such comparisons do not disprove the occurrence in organic forms, of changes great enough to produce what are called different types. The result of inductive inquiry we saw to be, that while a few modern higher types yield signs of having been developed from ancient lower types; and while there are many modern types which may have been thus developed, though we are without evidence that they have been so; yet that "any admissible hypothesis of progressive modification must be compatible with persistence without progression through indefinite periods." Now these results are quite congruous with the hypothesis of evolution. As rationally interpreted, evolution must in all cases be understood to result, directly or indirectly, from the incidence of forces. If there are no changes of conditions, entailing organic changes, organic changes are not to be expected. Only in organisms which fall under conditions, in conformity to which there arise additional modifications answering to additional needs, will there be that increased heterogeneity which characterizes higher forms. Hence, though the facts of palæontology cannot be held to prove evolution, yet they are in harmony with it; and some few of them yield it support.

§ 141. One general truth respecting distribution in Time, is, however, profoundly significant. If, instead of contemplating the relations among past forms of life taken by themselves, we contemplate the relations between them and the forms now existing; we find a connexion which is in perfect harmony with the belief in evolution, but quite irreconcilable with any other belief.

Note, first, how full of meaning is the close kinship that exists between the aggregate of organisms now living, and the aggregate of organisms which lived in the most recent geologic times. In the last-formed strata, nearly all the imbedded remains are those of species which still flourish. Strata a little older, contain a few fossils of species now extinct; though, usually, species greatly resembling extant ones. Of the remains found in strata of still earlier date, the extinct species form a larger per centage; and the differences between them and the allied species now living, are more marked. That is to say, the gradual change of organic types in Time, which we before saw is indicated by the geological record, is equally indicated by the relation between existing organic types and organic types of the epoch preceding our own. The evidence completely accords with the belief in a descent of present life from past life. Doubtless such a kinship is not incongruous with the doctrine of special creations. It may be argued that the introduction, from time to time, of new species better fitted to the somewhat changed conditions of the Earth's surface, would result in an apparent alliance between our living Flora and Fauna, and the Floras and Faunas that lately lived. No one can deny it. But on passing from the most general aspect of the alliance, to its more special aspects, we shall find this interpretation completely negatived.

For besides a close kinship between the aggregate of surviving forms and the aggregate of forms that have died out in recent geologic times; there is a peculiar connexion of like nature between present and past forms in each great geographical region. The instructive fact before cited from Mr Darwin, is the "wonderful relationship in the same continent between the dead and the living." This relationship is not explained by the supposition that new species have been at intervals supernaturally placed in each habitat, as the habitat became modified; since, as we saw, species are by no means uniformly found in the habitats to which they are best adapted. It cannot be said that the marsupials imbedded in recent Australian strata, having become extinct because of unfitness to some new external condition, the existing marsupials were then specially created to fit the modified environment; since sundry animals found elsewhere, are so much more completely in harmony with these new Australian conditions, that, when taken to Australia, they rapidly extrude the marsupials. While, therefore, the similarity between the existing Australian Fauna and the Fauna which immediately preceded it over the same area, is just that which the belief in evolution leads us to expect; it is a similarity which cannot be otherwise accounted for.

CHAPTER VIII.

HOW IS ORGANIC EVOLUTION CAUSED?

§ 143. Already it has been necessary to speak of the causes of organic evolution in general terms; and now we are prepared for considering them specifically. The task before us is to deduce the leading facts of organic evolution, from those same first principles which evolution at large conforms to.

Before attempting this, however, it will be instructive to glance at the causes of organic evolution that have been from time to time alleged.

§ 144. The theory that plants and animals of all kinds were gradually evolved, seems to have been at first accompanied only by the vaguest conception of cause—or rather, by no conception of cause properly so called, but only by the blank form of a conception. One of the earliest who in modern times (1735) contended that organisms are indefinitely modifiable, and that through their modifications they have become adapted to various modes of existence, was De Maillet. But though De Maillet supposed all living beings to have arisen by a natural, continuous process, he does not appear to have had any definite idea of that which determines this process. In 1794, in his *Zoonomia*, Dr Darwin gave reasons (sundry of them valid ones) for believing that organized beings of every kind, have descended from one, or a few, primordial germs; and along with some observable causes of modification, which he points out as aiding the developmental process, he apparently ascribes it, in part, to a tendency given to such germ or germs when created. He suggests the possibility "that all warm-blooded animals have arisen from one living filament, which THE GREAT FIRST CAUSE endued with animality, with the power of acquiring new parts, attended with new propensities, directed by irritations, sensations, volitions, and associations; and thus possessing the faculty of continuing to improve by its own inherent activity." In this passage we see the idea to be, that evolution is pre-determined by some intrinsic proclivity. "It is curious," says Mr Charles Darwin, "how largely my grandfather, Dr Erasmus Darwin, anticipated the erroneous grounds of opinion, and the views of Lamarck." One of the anticipations was this ascription of development to some inherent tendency. To the "plan général de la nature, et sa marche uniforme dans ses opérations," Lamarck attributes "la progression évidente qui existe dans la composition de l'organisation des animaux;" and "la *gradation* régulière qu'ils devroient offrir dans la composition de leur organisation," he thinks is rendered irregular by secondary causes. Essentially the same in kind, though somewhat different in form, was the conception put forth in the *Vestiges of Creation;* the author of which contends "that the several series of animated beings, from the simplest and oldest up to the highest and most recent, are, under the providence of God, the results, *first*, of an impulse which has been imparted to the forms of life, advancing them, in definite times, by generation, through grades of organization terminating in the highest dicotyledons and vertebrata;" and that the progression resulting from those impulses, is modified by certain other causes. The broad general contrasts between lower and higher forms of life, are regarded by him as due to an innate aptitude to give birth to forms of more perfect structures. The last to re-enunciate this doctrine has been Prof. Owen; who asserts "the axiom of the continuous operation of creative power, or of the ordained becoming of living things." Though these highly-general expressions do not suggest any very definite idea, yet they imply the belief that organic progress is a result of some in-dwelling tendency to develop, supernaturally impressed on living matter at the outset—some ever-acting constructive force, which, independently of other forces, moulds organisms into higher and higher forms.

In whatever way it is formulated, or by whatever language it is obscured, this ascription of organic evolution to some aptitude naturally possessed by organisms, or miraculously imposed on them, is unphilosophical. It is one of those explanations which explains nothing—a shaping of ignorance into the semblance of knowledge. The cause assigned is not a true cause—not a cause assimilable to known causes—not a cause that can be anywhere shown to produce analogous effects. It is a cause unrepresentable in thought: one of those illegitimate symbolic conceptions which cannot by any mental process be elaborated into a real conception. In brief, this assumption of a persistent formative power, inherent in organisms, and making them unfold into higher forms, is an assumption no more tenable than the assumption of special creations: of which, indeed, it is but a modification; differing only by the fusion of separate unknown processes into a continuous unknown process.

§ 145. Along with this intrinsic tendency to progress, supposed to be primordially impressed on them, Dr Darwin held that animals have a capacity for being modified by processes which their own desires initiate. He speaks of powers as "excited into action by the necessities of the creatures which possess them, and on which their existence depends;" and more specifically he says that "from their first rudiment or primordium, to the termination of their

wider knowledge of the facts, it is essentially the same as that of Dr Darwin; and along with the truth it contains, contains also the same error more distinctly pronounced. Merely noting that desires or wants, acting directly only on the nervo-muscular system, can have no immediate influence on very many organs, as the viscera, or such external appendages as hair and feathers; and observing, further, that even some parts which belong to the apparatus of external action, such as the bones of the skull, cannot be made to grow by increase of function called forth by desire; it will suffice to point out that the difficulty is not solved, but simply slurred-over, when needs or wants are introduced as independent causes of evolution. True though it is, as Dr Darwin and Lamarck contend, that desires, by leading to increased actions of motor organs, may induce further developments of such organs; and true as it probably is, that the modifications hence arising, are transmissible to offspring; yet there remains the unanswered question—Whence do these desires originate? The transferrence of the exciting power from the exterior to the interior, as described by Lamarck, begs the question. How comes there a wish to perform an action not before performed? Until some beneficial result has been felt from going through certain movements, what can suggest the execution of such movements? Every desire consists primarily of a mental representation of that which is desired, and secondarily excites a mental representation of the actions by which it is attained; and any such mental representations of the end and the means, imply antecedent experience of the end and antecedent use of the means. To assume that in the course of evolution there from time to time arose new kinds of actions dictated by new desires, is simply to remove the difficulty a step back.

§ 146. Changes of external conditions are named by Dr Darwin, as causes of modifications in organisms. Assigning, as evidence of original kinship, that marked similarity of type which exists among animals, he regards their deviations from one another, as caused by differences in their modes of life: such deviations being directly adaptive. Enumerating various appliances for procuring food, he says they all "seem to have been gradually produced during many generations by the perpetual endeavour of the creatures to supply the want of food, and to have been delivered to their posterity with constant improvement of them for the purposes required." And the creatures possessing these various appliances, are considered as having been rendered unlike, by seeking for food in unlike ways. As illustrating the alterations wrought by changed circumstances, he names the acquired characters of domestic animals. Lamarck has elaborated the same view in detail: using for the purpose, with great ingenuity, his extensive knowledge of the animal kingdom. From a passage in the *Avertissement*, it would at first sight seem, that he looks upon direct adaptation to new conditions, as the chief cause of evolution. He says—"Je regardai comme certain que le *mouvement des fluides* dans l'intérieur des animaux, mouvement qui c'est progressivement accéléré avec la composition plus grande de l'organisation; et que l'*influence des circonstances* nouvelles, à mesure que les animaux s'y exposèrent en se répandant dans tous les lieux habitables, furent les deux causes générales qui ont amené les différens animaux à l'état où nous les voyons actuellement." But elsewhere, the view he expresses appears decidedly different from this. He asserts that "dans sa marche, la nature a commencé, et recommence encore tous les jours, par former les corps organisés les plus simples;" and that "les premières ébauches de l'animal et du végétal étant formées dans les lieux et les circonstances convenables, les facultés d'une vie commençante et d'un mouvement organique établi, ont nécessairement développé peu à peu les organes, et qu'avec le temps elles les ont diversifiés ainsi que les parties." And then, further on, he puts in italics this proposition:—"*La progression dans la composition de l'or-*

ganisation subit, çà et là, dans la série générale des animaux, des anomalies opérées par l'influence des circonstances d'habitation, et par celle des habitudes contractées." These, and sundry other passages, joined with his general scheme of classification, make it clear that Lamarck conceived adaptive modification to be, not the cause of progression, but the cause of irregularities in progression. The inherent tendency which organisms have, to develop into more perfect forms, would, according to him, result in a uniform series of forms; but varieties in their conditions work divergences of structure, which break up the series into groups: groups which he nevertheless places in uni-serial order, and regards as still substantially composing an ascending succession.

§ 147. These speculations, crude as they may be considered, show much sagacity in their respective authors, and have done good service. Without embodying the truth in a definite shape, they contain adumbrations of it. Not directly, but by successive approximations, do mankind reach correct conclusions; and those who first think in the right direction, loose as may be their reasonings, and wide of the mark as their inferences may be, yield indispensable aid by framing provisional conceptions, and giving a bent to inquiry.

Contrasted with the dogmas of his age, the idea of De Maillet was a great advance. Before it can be ascertained how organized beings have been gradually evolved, there must be reached the conviction that they *have* been gradually evolved; and this conviction he reached. His wild notions as to the way in which natural agencies acted in the production of plants and animals, must not make us forget the merit of his intuition that animals and plants were produced by natural causes. In Dr Darwin's brief exposition, the belief in a progressive genesis of organisms, is joined with an interpretation having considerable definiteness and coherence. In the space of ten pages he not only indicates several of the leading classes of facts which support

the process of evolution of organisms, is affiliated on the process of evolution in general, can it be truly said to be explained. The thing required is to show that its various results are corollaries from first principles. We have to reconcile the facts with the universal laws of the re-distribution of matter and motion.

CHAPTER IX.

EXTERNAL FACTORS.

§ 148. WHEN illustrating the rhythm of motion (*First Principles*, § 94) it was pointed out that besides the daily and annual alternations in the quantities of light and heat which any portion of the Earth's surface receives from the Sun, there are alternations which require immensely-greater periods to complete. Reference was made to the fact, that "every planet, during a certain long period, presents more of its northern than of its southern hemisphere to the Sun at the time of its nearest approach to him; and then again, during a like period, presents more of its southern hemisphere than of its northern—a recurring co-incidence which, though causing in some planets no sensible alterations of climate, involves in the case of the Earth an epoch of 21,000 years, during which each hemisphere goes through a cycle of temperate seasons, and seasons that are extreme in their heat and cold." Further, it was pointed out that there is a variation of this variation. The slow rhythm of temperate and intemperate climates, which takes 21,000 years to complete, itself undergoes exaggeration and mitigation, during epochs that are far longer. The Earth's orbit slowly alters in form: now approximating to a circle; and now becoming more eccentric. During the period at which the Earth's orbit has least eccentricity, the temperate and intemperate climates which repeat their cycle in 21.000 years, are severally less temperate and less intemperate, than when, some one or two millions of years later, the Earth's orbit has reached its extreme of eccentricity.

Thus, besides those daily variations in the quantities of light and heat received by organisms, and responded to by variations in their functions; and besides the annual variations in the quantities of light and heat which organisms receive, and similarly respond to by variations in their functions; there are variations that severally complete themselves in 21,000 years and in some millions of years—variations to which there must also be a response in the changed functions of organisms. The whole vegetal and animal kingdoms, are subject to a quadruply-compounded rhythm in the incidence of the forces on which life primarily depends—a rhythm so involved in its slow working round, that at no time during one of these vast epochs, can the incidence of these forces be exactly the same as at any other time. To the direct effects so produced on organisms, have to be added much more important indirect effects. Changes of distribution must result. Certain redistributions are occasioned even by the annual variations in the quantities of the solar rays received by each part of the Earth's surface. The migrations of birds thus caused, are familiar. So too are the migrations of certain fishes: in some cases from one part of the sea to another; and in some cases from salt water to fresh water. Now just as the yearly changes in the amounts of light and heat falling on each locality, yearly extend and restrict the habitats of many organisms that are able to move about with some rapidity; so must these alternations of temperate and intemperate climates produce extensions and restrictions of habitats. These extensions and restrictions, though slow, will be universal—will affect the habitats of stationary organisms as well as those of locomotive ones. For if during an astronomic era, there is going on at any limit to a plant's habitat, a diminution of the winter's cold or summer's heat, which had before stopped its spread at

Earth, to sets of incident forces which differ from previous sets, both by changes in the proportions of the factors, and, occasionally, by the addition of new factors.

§ 150. Variations in the astronomical conditions joined with variations in the geological conditions, bring about variations in the meteorological conditions. Those extremely slow alternations of elevation and subsidence, which there is reason to believe take place over immense areas, here producing a continent where once there was a fathomless ocean, and there causing wide seas to spread where in a long past epoch there stood snow-capped mountains, gradually work great atmospheric changes. While yet the highest parts of an emerging surface of the Earth's crust, exist as a cluster of islands, the plants and animals which in course of time migrate to them, have climates that are peculiar to small tracts of land surrounded by large tracts of water. As, by successive upheavals, greater areas are exposed, there begin to arise sensible contrasts between the states of their peripheral parts and their central parts: the sea and land breezes, which daily moderate the extremes of temperature near the shores, cease to affect the interiors; and the interiors, less qualified too in their heat and cold by such ocean-currents as bathe the shores, acquire more decidedly the characters due to their latitudes. Along with the further elevations which unite the members of the archipelago into a continent, there come new meteorologic changes, as well as exacerbations of the old. The winds, which were comparatively uniform in their directions and periods when only islands existed, grow involved in their distribution, and widely-different in different parts of the continent. The quantities of rain which they discharge and of moisture which they absorb, vary everywhere according to the proximity to the sea and to surfaces of land having special characters.

Other complications result from variations of height above the sea: elevation producing a decrease of heat and conse-

on the average, the organic environments of organisms have been increasing in heterogeneity. As the number of species with which each species is directly or indirectly implicated, multiplies, each species is oftener subject to changes in the organic actions which influence it. These more frequent changes severally grow more involved. And the corresponding reactions affect larger Floras and Faunas, in ways increasingly complex and varied.

§ 152. When the astronomic, geologic, meteorologic, and organic agencies that are at work on each species of organism, are contemplated as becoming severally more complicated in themselves, and at the same time as co-operating in ways that are always more or less new; it will be seen that throughout all time, there has been an exposure of organisms to endless successions of modifying causes which gradually acquire an intricacy that is scarcely conceivable. Every kind of plant and animal may be regarded as for ever passing into a new environment—as perpetually having its relations to external circumstances altered, either by their changes with respect to it when it remains stationary, or by its changes with respect to them when it migrates, or by both.

Yet a further cause of progressive alteration and complication in the incident forces, exists. All other things continuing the same, every additional faculty by which an organism is brought into relation with external objects, as well as every improvement in such faculty, becomes a means of subjecting the organism to a greater number and variety of external stimuli, and to new combinations of external stimuli. So that each advance in complexity of organization, itself becomes an added source of complexity in the incidence of external forces.

Once more, every increase in the locomotive powers of animals, increases both the multiplicity and the multiformity of the actions of things upon them, and of their reactions upon things. Doubling a creature's activity, quadruples the area that comes within the range of its excursions: thus augmenting in number and heterogeneity, the external agencies which act on it during any given interval.

By compounding the actions of these several orders of factors, there is produced a geometric progression of changes, increasing with immense rapidity. And there goes on an equally rapid increase in the frequency with which the combinations of the actions are altered, and the intricacies of their co-operations enhanced.

CHAPTER X.

INTERNAL FACTORS.

§ 153. We saw at the outset (§§ 10—16), that organic matter is built up of molecules so extremely unstable, that the slightest variation in their conditions destroys their equilibrium; and causes them either to assume altered structures or to decompose. But a substance which is beyond all others changeable by the actions and reactions of the forces liberated from instant to instant within its own mass, must be a substance that is beyond all others changeable by the forces acting on it from without. If their composition fits organic aggregates for undergoing with special facility and rapidity those re-distributions of matter and motion whence result individual organization and life; then their composition must make them similarly apt to undergo those permanent re-distributions of matter and motion which are expressed by changes of structure, in correspondence with permanent re-distributions of matter and motion in their environments.

Already in *First Principles*, when considering the phenomena of Evolution in general, the leading characters and causes of those changes which constitute organic evolution, were briefly traced. Under each of the derivative laws of force to which the passage from an incoherent, indefinite homogeneity to a coherent, definite heterogeneity, conforms, were given illustrations drawn from the metamorphoses of

tinue through successive individuals. Given a series of organisms, each of which is developed from a portion of a preceding organism, and the question is, whether, after exposure of the series for a million years to changed incident forces, one of its members will be the same as though the incident forces had only just changed. To say that it will, is implicitly to deny the persistence of force. In relation to any cause of divergence, the whole series of such organisms may be considered as fused together into a continuously-existing organism; and when so considered, it becomes manifest that a continuously-acting cause will go on working a continuously-increasing effect, until some counteracting cause prevents any further effect.

But now if any primordial organic aggregate, must, in itself and through its descendants, gravitate from uniformity to multiformity, in obedience to the more or less multiform forces acting on it; what must happen if these multiform forces are themselves ever undergoing slow variations and complications? Clearly the process, ever-advancing towards a temporary limit but ever having its limit removed, must go on unceasingly. On those structural changes wrought in the once homogeneous aggregate by an original set of incident forces, will be superposed further changes wrought by a modified set of incident forces; and so on throughout all time. Omitting for the present those circumstances which check and qualify its consequences, the instability of the homogeneous must be recognized an ever-acting cause of organic evolution, as of all other evolution.

While it follows that every organism, considered as an individual and as one of a series, tends thus to pass into a more heterogeneous state; it also follows that every species, considered as an aggregate of individuals, tends to do the like. Throughout the area it inhabits, the conditions can never be absolutely uniform: its members must, in different parts of its area, be exposed to different sets of incident forces. Still more decided must this difference of exposure be when its members spread into other habitats. Those expansive and repressive energies which set to each species a limit that perpetually oscillates from side to side of a certain mean, are, as we lately saw, frequently changed by new combinations of the external factors—astronomic, geologic, meteorologic, and organic. Hence there from time to time arise lines of diminished resistance, along which the species flows into new localities. Such portions of the species as thus migrate, are subject to circumstances markedly contrasted with its average circumstances. And from multiformity of the circumstances, must come multiformity of the species.

Thus the law of the instability of the homogeneous, has here a three-fold corollary. As interpreted in connexion with the ever-progressing, ever-complicating changes in external factors, it brings us to the conclusion that there must be a prevailing tendency towards greater heterogeneity in all kinds of organisms, considered both individually and in successive generations; as well as in each assemblage of organisms constituting a species; and, by consequence, in each genus, order, and class

§ 155. When considering the causes of evolution in general, we further saw (*First Principles*, § 116), that the multiplication of effects aids continually to increase that heterogeneity into which homogeneity inevitably lapses. It was pointed out that since "the several parts of an aggregate are differently modified by any incident force;" and that since "by the reactions of the differently modified parts the incident force itself must be divided into differently modified parts;" it follows that "each differentiated division of the aggregate thus becomes a centre from which a differentiated division of the original force is again diffused. And since unlike forces must produce unlike results, each of these differentiated forces must produce, throughout the aggregate, a further series of differentiations." And to this it was added, that in proportion as the heterogeneity increases, the complications arising from this multiplication of effects grow more marked; since the more strongly contrasted the parts of an aggregate become, the more different must be their reactions upon incident forces, and the more unlike must be the secondary sets of effects which these modified incident forces initiate; and since every increase in the number of unlike parts increases the number of such differentiated incident forces, and such secondary sets of effects.

How this multiplication of effects conspires with the instability of the homogeneous, to work an increasing multiformity of structure in an organism, was shown at the time; and the foregoing pages contain further incidental illustrations. Under the head of Adaptation (§ 69), it was shown that a change in one function must act and re-act through ever-complicating perturbations on the rest; and that, eventually, all parts of the organism must be modified in their states. Suppose that the head of a mammal becomes very much more weighty—what must be the indirect results? The muscles of the neck are put to greater exertions; and its vertebræ have to bear additional tensions and pressures, caused both by the increased weight of the head, and the stronger contractions of the muscles that support and move the head. These muscles also affect their own attachments: several of the dorsal spines have augmented strains put on them; and the vertebræ to which they are fixed, are more severely taxed. Further, this heavier head and the more massive neck it necessitates, require a stronger fulcrum: the whole thoracic arch, and the fore limbs which support it, are subject to greater continuous stress and more violent occasional shocks. And the required strengthening of the fore-quarters cannot take place, without the centre of gravity being changed, and the hind limbs being differently reacted upon during locomotion. Any one who compares the outline of the bison with that of its congener, the ox, will clearly see how profoundly a heavier head affects the entire compages

cause of increasing multiformity. The lapse of a species into divergent varieties, initiates fresh combinations of forces tending to work further divergences. The new varieties compete with the parent species in new ways; and so add new elements to its circumstances. They modify somewhat the conditions of other species existing in their habitat, or into whose habitat they have spread; and the modifications wrought in such other species, become additional sources of influence. The Flora and Fauna of every region are united by their entangled relations into a whole, of which no part can be affected without affecting the rest. Hence, each differentiation in a local assemblage of species, becomes the cause of further differentiations in such assemblage.

§ 150. One of the universal principles to which we saw that the re-distribution of matter and motion conforms, is that in any aggregate made up of mixed units, incident forces produce segregation—separate unlike units and unite like units; and it was shown that the increasing integration and definiteness which characterizes each part of an evolving organic aggregate, as of every other aggregate, results from this (*First Principles*, § 126). It remains here to be pointed out, that while the actions and reactions going on between organisms and their ever-changing environments, add to the heterogeneity of organic structures, they also give to the heterogeneity this growing distinctness. At first sight the reverse might be inferred. It might be argued that any new set of effects wrought in an organism by some new set of external forces, must tend more or less to obliterate the effects previously wrought—must produce confusion or indefiniteness. A little consideration, however, will dissipate this impression.

Doubtless the condition under which alone increasing definiteness of structure can be acquired by any part of an organism, either in an individual or in successive generations, is that such part shall be exposed to some set of tolerably-constant forces; and doubtless, continual change of circumstances interferes with this. But the interference can never be considerable. For the pre-existing structure of an organism prevents it from living under any new conditions except such as are congruous with the fundamental characters of its organization—such as subject its essential organs to actions substantially the same as before. Great changes must kill it. Hence, it can continuously expose itself and its descendants, only to those moderate changes which do not destroy the general harmony between the aggregate of incident forces and the aggregate of its functions. That is, it must remain under influences calculated to make greater the definiteness of the chief differentiations already produced. If, for example, we set out with an animal in which a rudimentary vertebral column with its attached muscular system has been established; it is clear that the mechanical arrangements have become thereby so far determined, that subsequent modifications are extremely likely, if not certain, to be consistent with the production of movement by the action of muscles on a flexible central axis. Hence, there will continue a general similarity in the play of forces to which the flexible central axis is subject; and so, notwithstanding the metamorphoses which the vertebrate type undergoes, there will be a maintenance of conditions favourable to increasing definiteness and integration of the vertebral column. Moreover, this maintenance of such conditions becomes secure in proportion as organization advances. Each further complexity of structure, implying some further complexity in the relations between an organism and its environment, must tend to specialize the actions and reactions between it and its environment—must tend to increase the stringency with which it is restrained within such environments as admit of those special actions and reactions for which its structure fits it; that is, must further guarantee the continuance of those actions and reactions to which its essential organs respond, and therefore the continuance of the segregating process.

How in each species, considered as an aggregate of individuals, there must arise stronger and stronger contrasts between those divergent varieties which result from the instability of the homogeneous and the multiplication of effects, needs only be briefly indicated. It has already been shown (*First Principles*, § 126), that in conformity to the universal law that mixed units are segregated by like incident forces, there are produced increasingly-definite distinctions among varieties, wherever there occur definitely-distinguished sets of conditions to which the varieties are respectively subject.

§ 157. Probably in the minds of some, the reading of this chapter has been accompanied by a running commentary, to the effect that the argument proves too much. The apparent implication is, that the passage from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity in organic aggregates, must have been going on universally; whereas we find that in many cases there has been persistence without progression. This apparent implication, however, is not a real one.

For though every environment on the Earth's surface undergoes changes; and though usually the organisms which each environment contains, cannot escape certain resulting new influences; yet occasionally such new influences are escaped, by the survival of species in the unchanged parts of their habitats, or by their spread into neighbouring habitats which the change has rendered like their original habitats, or by both. Any alteration in the temperature of a climate or its degree of humidity, is unlikely to affect simultaneously the whole area occupied by a species; and further, it can scarcely fail to happen that the addition or subtraction of heat or moisture, will give to a part of some adjacent area, a climate like to that to which the species has been habituated. If, again, the circumstances of a species are modified by the intrusion of some foreign

distinct complexity. Unless we deny the persistence of force, we must admit that the gravitation of an organism's structure from an indefinitely homogeneous to a definitely heterogeneous state, must be cumulative in successive generations, if the forces causing it continue to act. And for the like reasons, the increasing assemblage of individuals arising from a common stock, is also liable to lose its original uniformity; and, in successive generations, to grow more pronounced in its multiformity.

These changes, which would go on to but a comparatively small extent were organisms exposed to constant external conditions, are kept up by the continual changes in external conditions, produced by astronomic, geologic, meteorologic, and organic agencies: the average result being, that on previous complications of structure wrought by previous incident forces, new complications are continually superposed by new incident forces. And hence simultaneously arises increasing heterogeneity in the structures of individuals, in the structures of species, and in the structures of the Earth's Flora and Fauna.

But while, in very many or in most cases, the ever-changing incidence of forces is ever adding to the complexity of organisms, and to the complexity of the organic world as a whole; it does this only where its action cannot be eluded. And since, by migration, it is possible for species to keep themselves under conditions that are tolerably constant; there must be a proportion of cases in which greater heterogeneity of structure is not produced.

Uniting these three propositions, we are brought to a conclusion which, so far as it goes, appears to be in harmony with the facts. We find progression to result, not from a special, inherent tendency of living bodies, but from a general average effect of their relations to surrounding agencies. While we are not called on to suppose that there exists in organisms any primordial impulse which makes them continually unfold into more heterogeneous forms; we see

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that a liability to be unfolded arises from the actions and reactions between organisms and their fluctuating environments. And we see that the existence of such a cause of development, presupposes the non-occurrence of development where this fluctuation of actions and reactions does not come into play.

To show, however, that there must arise a certain general tendency to the production of more heterogeneous aggregates, is not sufficient. It is quite conceivable that aggregates should be rendered more heterogeneous by changing incident forces, without having given to them that peculiar form of heterogeneity required for carrying on the functions of life. Hence it remains now to inquire, how the production and maintenance of this peculiar form of heterogeneity is insured.

CHAPTER XI.

DIRECT EQUILIBRATION.

§ 159. Every change is of necessity towards a balance of forces; and of necessity can never cease until a balance of forces is reached. When treating of equilibration under its general aspects (*First Principles*, Part II., Chap. xvi.), we saw that in every aggregate having compound movements, there tends continually to be established a moving equilibrium; since any unequilibrated force to which such an aggregate is subject, if not of a kind to overthrow the aggregate altogether, must continue modifying its state until an equilibrium is brought about. And we saw that the structure simultaneously reached must be "one presenting an arrangement of forces that counterbalance all the forces to which the aggregate is subject;" since, "so long as there remains a residual force in any direction—be it excess of a force exercised by the aggregate on its environment, or of a force exercised by its environment on the aggregate, equilibrium does not exist; and therefore the re-distribution of matter must continue."

It is essential that this truth should here be fully understood; and to the end of insuring a clear comprehension of it, some re-illustration is desirable. The case of the Solar System will best serve our purpose. An assemblage of bodies, each of which has its simple and compound motions, that severally alternate between two extremes, and the whole of

from without, a supply of force to replace the force which it expends; but this continual giving to its parts a new momentum, to make up for the momentum continually lost, does not interfere with the carrying on of actions and reactions like those just described. Here, as before, we have a definitely-arranged aggregate of parts, which we call organs, having their definitely-established actions and reactions, which we call functions. These rhythmical actions or functions, and the various compound rhythms resulting from their combinations, are in such adjustment as to balance the actions to which the organism is subject: there is a constant or periodic genesis of forces, which, in their kinds, amounts, and directions, suffice to antagonize the forces which the organism has constantly or periodically to bear. If then there exists this state of moving equilibrium among a definite set of internal actions, exposed to a definite set of external actions; what must result if any of the external actions are changed? Of course there is no longer an equilibrium. Some force which the organism habitually generates, is too great or too small to balance some incident force; and there arises a residuary force exerted by the environment on the organism, or by the organism on the environment. This residuary force—this unbalanced force, of necessity expends itself in producing some change of state in the organism. Acting directly on some organ and modifying its function, it indirectly modifies dependent functions, and remotely influences all the functions. As we have already seen (§§ 68, 69), if this new force is permanent, its effects must be gradually diffused throughout the entire system; until it has come to be equilibrated in working those structural re-arrangements which produce an exactly counterbalancing force.

The bearing of this general truth on the question we are now dealing with, is obvious. Those modifications upon modifications, which the unceasing mutations of their environments have been all along generating in organisms, have been in each case modifications involved by the establishment of a new balance with the new combination of conditions. In every species throughout all geologic time, there has been perpetually going on a rectification of the equilibrium, that has been perpetually disturbed by the alteration of surrounding circumstances; and every further heterogeneity has been the addition of a structural change entailed by a new equilibration, to the structural changes entailed by previous equilibrations. There can be no other ultimate interpretation of the matter, since change can have no other goal. Any fresh force brought to bear on an aggregate in a state of moving equilibrium, must do one of two things: it must either overthrow the moving equilibrium altogether, or it must alter without overthrowing it; and the alteration must end in the establishment of a new moving equilibrium. Hence in organisms, death or restoration of the physiological balance, are the only alternatives.

This equilibration between the functions of an organism and the actions in its environment, may be either direct or indirect. The new incident force may either immediately call forth some counteracting force, and its concomitant structural change; or it may be eventually balanced by some otherwise-produced change of function and structure. These two processes of equilibration are quite distinct, and must be separately dealt with. We will devote this chapter to the first of them.

§ 160. Direct equilibration is that process currently known as *adaptation*. We have already seen (Part II., Chap. v.), that individual organisms become modified when placed in new conditions of life—so modified as to re-adjust the powers to the requirements; and though there is great difficulty in disentangling the evidence, we found reason for thinking (§ 82) that structural changes thus caused by functional changes are inherited. In the last chapter, it was argued that if, instead of the succession of individuals constituting a species, there were a continuously-existing individual, any such functional and structural divergence as we see produced by a new incident force, would necessarily go on increasing until the new incident force was counterpoised; and that the replacing of a continuously-existing individual by a succession of individuals, each formed out of the modified substance of its predecessor, will not prevent the like effect from being produced—the persistence of force negativing any other inference. Here we further find, that this limit towards which any such organic change advances, in the species as in the individual, is a new moving equilibrium adjusted to the new arrangement of external forces.

But now, what are the conditions under which alone, direct equilibration can occur? Are all the modifications that serve to re-fit organisms to their environments, directly adaptive modifications? And if otherwise, which are the directly adaptive and which are not? How are we to distinguish between them?

Manifestly, for any moving equilibrium to be gradually altered, it is needful, first, that some force shall operate upon it; and, second, that the force shall not be such as to overthrow it. If in the environment there exists some agency that would act advantageously on an organism were the organism a little modified, but which does not act on it in the absence of the required modification; it is clear that this agency cannot itself tend to produce the modification. On the other hand, if the external agency be of such kind, that individuals of the species whenever affected by it, are either killed or so injured that the production of vigorous offspring is much interfered with, there cannot be directly wrought in the species, any such alteration as will fit it to cope with this external agency. The only new incident forces which can work the changes of function and structure required to bring any animal or plant into equilibrium with them, are such incident forces as operate on this animal or plant, either continuously or frequently. They must be capable

between the actions in the organism and the actions in its environment; seeing that all other things remaining the same, if these defences were absent, the destruction by herbivorous animals would be so increased, that the number of young plants annually produced would not suffice, as it now does, to balance the mortality, and the species would therefore disappear. But these defensive appliances, though they aid in maintaining the balance between inner and outer actions, cannot have been directly called forth by the outer actions which they serve to neutralize; for these outer actions do not continuously affect the functions of the plant even in a general way, still less in the special way required. Suppose a species of nettle bare of poison-hairs, to be habitually eaten by some mammal intruding on its habitat; the agency of this mammal would have no direct tendency to develop poison-hairs in the plant; since the individuals devoured could not bequeath changes of structure, even were the actions of a kind to produce them; and since the individuals that perpetuated themselves, would be those on which the new incident force had not fallen. Another class of organs similarly circumstanced, are those of reproduction. Like the organs of defence, these are not, during the life of the individual plant, variably exercised by variable external actions; and therefore do not fulfill those conditions under which structural changes may be directly caused by changes in the environment. The generative apparatus contained in every flower, acts only once during its existence; and even then, the parts subserve their ends in a passive rather than an active way. Functionally-produced modifications are therefore out of the question. If a plant's anthers are so placed, that the insect which most commonly frequents its flowers, is sure to come in contact with the pollen, and to fertilize with it other flowers of the same species; and if this insect, dwindling away or disappearing from the locality, leaves behind no insects that have such shapes and habits as cause them to do the same thing efficiently, but only some which do it inefficiently; it is clear that the change of its conditions, has no immediate tendency to work in the plant any such structural change as shall bring about a new balance with its conditions. For the anthers, which, even when they discharge their functions, do it simply by standing in the way of the insect, are, under the supposed circumstances, left untouched by the insect; and this remaining untouched, cannot have the effect of so modifying the stamens as to bring the anthers into a position to be touched by some other insect. Only those individuals whose parts of fructification so far differed from the average form of the species, that some other insect could serve them as pollen-carrier, would be sufficiently prolific to have good chances of perpetuating themselves. And on their progeny, inheriting the deviation, there would act no external force directly calculated to make the deviation greater, and the adaptation more complete; since the new circumstances to which re-adaptation is required, are such as do not in the least alter the equilibrium of functions constituting the life of the individual plant.

§ 162. Among animals, adaptation by direct equilibration is similarly traceable, wherever, during the life of the individual, an external change generates some constant or repeated change of function. This is conspicuously the case with such parts of an animal as are immediately exposed to diffused influences, like those of climate, and with such parts of an animal as are occupied in its mechanical actions on the environment. Of the one class of cases, the darkening or lightening of the skin, that follows exposure to greater or less heat, may be taken as an instance; and with the other class of cases, we are made familiar by the increase and decrease which use and disuse cause in the organs of motion and manipulation. It is needless here to exemplify these: they were treated of in the Second Part of this work.

But in animals, as in plants, there are many indispensable offices fulfilled by parts, between which and the external conditions they respond to, there is no such action and reaction as can directly produce an equilibrium. This is especially manifest with dermal appendages. Some ground, perhaps, exists for the conclusion that the greater or less development of hairs, is in part immediately due to increase or decrease of demand on their passive function, as non-conductors of heat; but be this as it may, it is impossible that there can exist any such cause for those immense developments of hairs which we see in the quills of the porcupine, or those complex developments of them known as feathers. Such an enamelled armour as is worn by the *Lepidosteus*, is inexplicable as a direct result of any functionally-worked change. For purposes of defence, such an armour is as needful, or more needful, for hosts of other fishes; and did it result from any direct reaction of the organism against any offensive actions it was subject to, there seems no reason why other fishes should not have developed similar protective coverings. Of sundry reproductive appliances, the like may be said. The secretion of an egg-shell round the substance of an egg, in the oviduct of a bird, is quite inexplicable as a consequence of some functionally-wrought modification of structure, immediately caused by some modification of external conditions. The end fulfilled by the egg-shell, is that of protecting the contained mass against certain slight pressures and collisions, to which it is liable during incubation. How, by any process of direct equilibration, could it come to have the required thickness? or, indeed, how could it come to exist at all? Suppose this protective envelope to be too weak, so that some of the eggs a bird lays are broken or cracked. In the first place, the breakages or crackings are actions of a kind which cannot react on the maternal organism, in such way as to cause the secretion of thicker shells for the future: to suppose that they can, is to suppose that the bird understands the cause of the evil, and that the secretion of thicker or thinner shells can be controlled by its

§ 163. The conclusion at which we arrive is, then, that there go on in all organisms, certain changes of function and structure that are directly consequent on changes in the incident forces—inner changes by which the outer changes are balanced, and the equilibrium restored. Such re-equilibrations, which are often conspicuously exhibited in individuals, we have reason to believe continue in successive generations; until they are completed by the arrival at structures fitted to the modified conditions. But, at the same time, we see that the modified conditions to which organisms may be adapted by direct equilibration, are conditions of certain classes only. That a new external action may be met by a new internal action, it is needful that it shall either continuously or frequently be borne by the individuals of the species, without killing or seriously injuring them; and shall act in such way as to affect their functions. And we find on examination, that many of the environing changes to which organisms have to be adjusted, are not of these kinds: being changes which either do not immediately affect the functions at all, or else affect them in ways that prove fatal.

Hence there must be at work some other process, which equilibrates the actions of organisms with the actions they are exposed to. Plants and animals that continue to exist, are necessarily plants and animals whose powers balance the powers that act on them; and as their environments change, the changes which plants and animals undergo, must necessarily be changes towards a re-establishment of the balance. Besides direct equilibration, there must therefore be an indirect equilibration. How this goes on we have now to inquire.

CHAPTER XII.

INDIRECT EQUILIBRATION.

§ 164. BESIDES those perturbations produced in the moving equilibrium of any organism by special disturbing forces, there are ever going on many other perturbations—some which are the still-reverberating effects of disturbing forces previously experienced by the individual, and others which are the still-reverberating effects of disturbing forces experienced by ancestral individuals; and the multiplied deviations of function so caused, imply multiplied deviations of structure. In § 155 there was re-illustrated the truth, set forth at length when treating of Adaptation (§ 69), that an organism in a state of moving equilibrium, cannot have extra function thrown on any organ, and extra growth produced in such organ, without there being entailed correlative changes throughout all other functions, and eventually throughout all other organs. And when treating of Variation (§ 90), we saw that individuals which have been made, by their different circumstances, to deviate functionally and structurally from the average type in different directions, will bequeath to their joint offspring, compound perturbations of function and compound deviations of structure, endlessly varied in their kinds and amounts. That is to say, besides the primary perturbations and deviations directly caused in organisms by altered actions in their environments, there are ever being indirectly caused, secondary and tertiary perturbations and deviations, which, when compounded with one another from generation to generation, work innumerable slight modifications in the moving equilibria and correlative structures throughout the species.

Now if the individuals of a species are thus necessarily made unlike, in countless ways and degrees—if the complicated sets of rhythms which we call their functions, though similar in their general characters, are dissimilar in their details—if in one individual the amount of action in a particular direction is greater than in any other individual, or if here a peculiar combination gives a resulting force which is not found elsewhere; then, among all the individuals, some will be less liable than others to have their equilibria overthrown by a particular incident force, previously unexperienced. Unless the change in the environment is of so violent a kind as to be universally fatal to the species, it must affect more or less differently the slightly different moving equilibria which the members of the species present. It cannot but happen that some will be more stable than others, when exposed to this new or altered factor. That is to say, it cannot but happen that those individuals whose functions are most out of equilibrium with the modified aggregate of external forces, will be those to die; and that those will survive whose functions happen to be most nearly in equilibrium with the modified aggregate of external forces.

But this survival of the fittest, implies multiplication of the fittest. Out of the fittest thus multiplied, there will, as before, be an overthrowing of the moving equilibrium wherever it presents the least opposing force to the new incident force. And by the continual destruction of the individuals that are the least capable of maintaining their equilibria in presence of this new incident force, there must eventually be arrived at an altered type completely in equilibrium with the altered conditions.

§ 165. This survival of the fittest, which I have here

win has been the first to perceive. To him we owe the discovery that natural selection is capable of producing fitness between organisms and their circumstances; and he, too, has the merit of appreciating the immensely-important consequences that follow from this. He has worked up an enormous mass of evidence into an elaborate demonstration, that this "preservation of favoured races in the struggle for life," is an ever-acting cause of divergence among organic forms. He has traced out the involved results of the process with marvellous subtlety. He has shown how hosts of otherwise inexplicable facts, are fully accounted for by it. In brief, he has proved that the cause he alleges is a true cause; that it is a cause which we see habitually in action; and that the results to be inferred from it, are in harmony with the phenomena which the Organic Creation presents, both as a whole and in its details. Let us glance at a few of the more important interpretations which the hypothesis furnishes.

A soil possessing some ingredient in unusual quantity, may supply to a plant an excess of the matter required for a certain class of its tissues; and may cause all the parts formed of such tissues to be abnormally developed. Suppose that among these are the hairs clothing its surfaces, including those which grow on its seeds. Thus furnished with somewhat longer fibres, its seeds, when shed, are carried a little further by the wind before they fall to the ground. The young plants growing up from them, being rather more widely dispersed than those produced by other individuals of the same species, will be less liable to smother one another; and a greater number may therefore reach maturity and fructify. Supposing the next generation subject to the same peculiarity of nutrition, some of the seeds borne by its members will not simply inherit this increased development of hairs, but will carry it further; and these, still more advantaged in the same way as before, will, on the average, have still more numerous chances of continuing the race. Thus, by the survival, generation after generation, of those possessing these longer hairs, and the inheritance of successive increments of growth in the hairs, there may result a seed deviating greatly from the original. Other individuals of the same species, subject to the different physical conditions of other localities, may develop somewhat thicker or harder coatings to their seeds: so rendering their seeds less digestible by the birds that devour them. Such thicker-coated seeds, by escaping undigested more frequently than thinner-coated ones, will have additional chances of growing up and leaving offspring; and this process, acting in a cumulative manner through successive years, will produce a seed diverging in another direction from the ancestral type. Again, elsewhere, some modification in the physiologic actions of the plant, may lead to an unusual secretion of an essential oil in the seeds; which rendering them unpalatable to creatures that would otherwise feed on them, may diminish the destruction of the seeds, so giving an advantage to the variety in its rate of multiplication; and this incidental peculiarity proving a preservative, will, as before, be gradually increased by natural selection, until it constitutes another divergence. Now in these and countless analogous cases, we see that plants may become better adapted, or re-adapted, to the aggregate of surrounding agencies, not through any *direct* action of such agencies upon them, but through their *indirect* action—through the destruction by them of the individuals which are least congruous with them, and the survival of those which are most congruous with them. All these slight variations of function and structure, arising among the members of a species, serve as so many experiments; the great majority of which fail, but a few of which succeed. Just as we see that each plant bears a multitude of seeds, out of which some two or three happen to fulfil all the conditions required for reaching maturity, and continuing the race; so we see that each species is perpetually producing numerous slightly-modified forms, deviating in all directions from the average, out of which most fit the surrounding conditions no better than their parents, or not so well, but some few of which fit the conditions better; and doing so, are enabled the better to preserve themselves, and to produce offspring similarly capable of preserving themselves. Among animals the like process results in the like development of various structures which cannot have been affected by the performance of functions—their functions being purely passive. The thick shell of a mollusk, is inexplicable as a result of direct reactions of the organism against the external actions to which it is exposed; but it is quite explicable as a result of the survival, generation after generation, of individuals whose thicker coverings protected them against enemies. Similarly with such a dermal structure as that of the tortoise. Though we have evidence that the skin where it is continually exposed to pressure and friction may thicken, and so re-establish the equilibrium, by opposing a greater inner force to a greater outer force; yet we have no evidence that a coat of armour like that of the tortoise can be so produced. Nor, indeed, are the conditions under which only its production in such a manner could be accounted for, fulfilled; since the surface of the tortoise is not exposed to greater pressure and friction than the surfaces of other creatures. This massive carapace, and the strangely-adapted osseous frame-work which supports it, are unaccountable as results of evolution, unless through the process of natural selection. Thus, too, is it with the production of colours in birds and in insects; the formation of odoriferous glands in mammals; the growth of such excrescences as those of the camel. Thus, in short, is it with all those organs of animals, which do not play active parts in the compound rhythms of their functions.

Besides giving us explanations of structural characters that are otherwise unaccountable, Mr Darwin shows how natural selection explains peculiar relations between individuals in certain species. Such facts as the dimorphism of the primrose and other flowers, he proves to be quite in harmony with his hypothesis, though stumbling-blocks to all

of natural selection, we know that there exists a balance among the powers of organs which habitually act together—such proportions among them, that no one has any considerable excess of efficiency. We see, for example, that throughout the vascular system, there is maintained an equilibrium between the powers, that is, the developments, of the component parts: in some cases, under excessive exertion, the heart gives way, and we have enlargement; in other cases the large arteries give way, and we have aneurisms; in other cases the minute blood-vessels give way—now bursting, now becoming chronically congested. That is to say, in the average constitution, no superfluous strength is possessed by any of the appliances for circulating the blood. Take, again, a set of motor organs. Great strain here causes the fibres of a muscle to tear. There the muscle does not yield but the tendon snaps. Elsewhere neither muscle nor tendon is damaged, but the bone breaks. Joining with these instances the general fact, that under the same adverse conditions, different individuals show their slight differences of constitution by going wrong some in one way and some in another; and that even in the same individual, similar adverse conditions will now affect one viscus and now another; it becomes manifest that though there cannot be maintained an accurate or absolute balance among the powers of the organs composing an organism, yet the excesses and deficiencies of power are extremely slight. That they must be extremely slight, is, as before said, a deduction from the hypothesis of natural selection. Mr Darwin himself argues "that natural selection is continually trying to economize in every part of the organization. If under changed conditions of life a structure before useful becomes less useful, any diminution, however slight, in its development, will be seized on by natural selection, for it will profit the individual not to have its nutriment wasted in building up an useless structure." In other words, if any muscle has more fibres than can be utilized, or if a bone be stronger than needful, no advantage results, but rather a disadvantage—a disadvantage which will decrease the chances of survival. Hence it becomes a corollary, that among any organs which habitually act in concert, an increase of one can be of no service unless there is a concomitant increase of the rest. The co-operative parts must vary together; otherwise variation will be detrimental. A stronger muscle must have a stronger bone to resist its contractions; must have stronger correlated muscles and ligaments to secure the neighbouring articulations; must have larger blood-vessels to bring it supplies; must have a more massive nerve to bring it stimulus, and some extra development of a nervous centre to supply this extra stimulus. The question arises, then,—does spontaneous variation occur simultaneously in all these co-operative parts? Have we any reason to think that they spontaneously increase or decrease together? The assumption that they do, seems to me untenable; and its untenability will, I think, become conspicuous if we take a case, and observe how extremely numerous and involved are the variations which must be supposed to occur together. In illustration of another point, we have already considered the modification required to accompany increased weight of the head. Instead of the bison, however, the moose deer, or the extinct Irish elk, will here best serve our purpose. In this species the male has enormously-developed horns, which are used for purposes of offence and defence. These horns, weighing upwards of a hundred-weight, are carried at great mechanical disadvantage—supported as they are along with the massive skull which bears them, at the extremity of the outstretched neck. Further, that these heavy horns may be of use in fighting, the supporting bones and muscles must be strong enough, not simply to carry them, but to put them in motion with the rapidity required for giving blows. Let us, then, ask how, by natural selection, this complex apparatus of bones and muscles can have been developed, *pari passu* with the horns? If we suppose the horns to have originally been of like size with those borne by other kinds of deer; and if we suppose that in certain individuals, they became larger by spontaneous variation; what would be the concomitant changes required to render their greater size useful? Other things equal, the blow given by a larger horn would be a blow given by a heavier mass moving at a smaller velocity: the momentum would be the same as before; and the area of contact with the body struck being somewhat increased, while the velocity was decreased, the injury done would be less. That the horns may become better weapons, the whole apparatus which moves them must be so strengthened as to impress more force on them, and to bear the more violent reactions of the blows given. The bones of the skull on which the horns are seated must be thickened; otherwise they will break. To render the thickening of these bones advantageous, the vertebræ of the neck must be further developed; and without the ligaments that hold together these vertebræ, and the muscles which move them, are also enlarged, nothing will be gained. Such modifications of the neck will be useless, or rather will be detrimental, if its fulcrum be not made capable of resisting intenser strains: the upper dorsal vertebræ and their spines must be strengthened, that they may withstand the more violent contractions of the neck-muscles; and like changes must be made on the scapular arch. Still more must there be required a simultaneous development of the bones and muscles of the fore-legs; since each of these extra growths in the horns, in the skull, in the neck, in the shoulders, adds to the burden which the fore-legs have to bear; unless this deer with its heavier horns, head, neck, and shoulders, had stronger fore-legs, it would not only suffer from loss of speed but would even fail in fight. Hence, to make larger horns of use, additional sizes must be acquired by numerous bones, muscles, and ligaments, as well as by the blood-vessels and nerves on which their actions depend. On calling to mind how the spraining of a single small muscle in the foot, incapacitates for walking, or how a

but demands many powers; in the same proportion do there arise obstacles to the increase of any particular power, by "the preservation of favoured races in the struggle for life." As fast as the faculties are multiplied, so fast does it become possible for the several members of a species to have various kinds of superiorities over one another. While one saves its life by higher speed, another does the like by clearer vision, another by keener scent, another by quicker hearing, another by greater strength, another by unusual power of enduring cold or hunger, another by special sagacity, another by special timidity, another by special courage; and others by other bodily and mental attributes. Now it is unquestionably true that, other things equal, each of these attributes, giving its possessor an extra chance of life, is likely to be transmitted to posterity. But there seems no reason to suppose that it will be increased in subsequent generations by natural selection. That it may be thus increased, the individuals not possessing more than average endowments of it, must be more frequently killed off than individuals highly endowed with it; and this can happen only when the attribute is one of greater importance, for the time being, than most of the other attributes. If those members of the species which have but ordinary shares of it, nevertheless survive by virtue of other superiorities which they severally possess; then it is not easy to see how this particular attribute can be developed by natural selection in subsequent generations. The probability seems rather to be, that by gamogenesis, this extra endowment will, on the average, be diminished in posterity—just serving in the long run to compensate the deficient endowments of other individuals, whose special powers lie in other directions; and so to keep up the normal structure of the species. The working out of the process is here somewhat difficult to follow; but it appears to me that as fast as the number of bodily and mental faculties increases, and as fast as the maintenance of life comes to depend less on the amount of any one, and more on the combined action of all; so fast does the production of specialities of character by natural selection alone, become difficult. Particularly does this seem to be so with a species so multitudinous in its powers as mankind; and above all does it seem to be so with such of the human powers as have but minor shares in aiding the struggle for life—the æsthetic faculties, for example.

It by no means follows, however, that in cases of this kind, and cases of the preceding kind, natural selection plays no part. Wherever it is not the chief agent in working organic changes, it is still, very generally, a secondary agent. The survival of the fittest must nearly always further the production of modifications which produce fitness; whether they be modifications that have arisen incidentally, or modifications that have been caused by direct adaptation. Evidently, those individuals whose constitutions or circumstances have facilitated the production in them of any structural change consequent on any functional change demanded by some new external condition, will be the individuals most likely to live and to leave descendants. There must be a natural selection of functionally-acquired peculiarities, as well as of incidental peculiarities; and hence such structural changes in a species as result from changes of habit necessitated by changed circumstances, natural selection will render more rapid than they would otherwise be.

There are, however, some modifications in the sizes and forms of parts, which cannot have been aided by natural selection; but which must have resulted wholly from the inheritance of functionally-produced alterations. The dwindling away of organs of which the undue sizes entail no appreciable evils, furnishes the best evidence of this. Take, for an example, that diminution of the jaws and teeth which characterizes the civilized races, as contrasted with the savage races.* How can the civilized races have been bene-

* I am indebted to Mr Flower for the opportunity of examining the collection of skulls in the Museum of the College of Surgeons for verification of this. Us.

fited in the struggle for life, by the slight decrease in these comparatively-small bones? No functional superiority possessed by a small jaw over a large jaw, in civilized life, can be named as having caused the more frequent survival of small-jawed individuals. The only advantage which smallness of jaw might be supposed to give, is the advantage of economized nutrition; and this could not be great enough to further the preservation of men possessing it. The decrease of weight in the jaw and co-operative parts, that has arisen in the course of many thousands of years, does not amount to more than a few ounces. This decrease has to be divided among the many generations that have lived and died in the interval. Let us admit that the weight of these parts diminished to the extent of an ounce in a single generation (which is a large admission); it still cannot be contended that the having to carry an ounce less in weight, or the having to keep in repair an ounce less of tissue, could sensibly affect any man's fate. And if it never did this—nay, if it did not cause a *frequent* survival of small-jawed individuals where large-jawed individuals died; natural selection could neither cause nor aid diminution of the jaw and

fortunately the absence, in most cases, of some or many teeth, prevented me from arriving at that specific result which would have been given by weighing a number of the under jaws in each race. Simple inspection, however, disclosed a sufficiently-conspicuous difference. The under jaws of Australians and Negroes, when placed side by side with those of Englishmen, were visibly larger, not only relatively but absolutely. One Australian jaw only, did I observe, that was about of the same actual size as an average English jaw; and this (probably the jaw of a woman) belonging as it did to a much smaller skull, bore a much greater ratio to the whole body of which it formed part, than did an English jaw of the same actual size. In all the other cases, the under jaws of these inferior races (containing larger teeth than our own) were *absolutely* more massive than our own—often exceeding them in all dimensions; and *relatively* to the smaller skeletons of these inferior races, they were very much more massive. Let me add that the Australian and Negro jaws are thus strongly contrasted, not with all British jaws, but only with the jaws of the civilized British. An ancient British skull in the collection, possesses a jaw almost or quite as massive as those of the Australian skulls. And this is in harmony with the alleged relation between greater size of jaws and greater action of jaws, involved by the habits of savages.

mical variations in these two sets of forces, there is maintained an oscillating limit to its habitat, and an oscillating limit to its numbers. On another occasion (§ 96) it was shown that the aggregate of individuals constituting a species, has a kind of general life, which, "like the life of an individual, is maintained by the unequal and ever-varying actions of incident forces on its different parts." We saw that "just as, in each organism, incident forces constantly produce divergences from the mean state in various directions, which are constantly balanced by opposite divergences indirectly produced by other incident forces; and just as the combination of rhythmical functions thus maintained, constitutes the life of the organism; so, in a species, there is through gamogenesis a perpetual neutralization of those contrary deviations from the mean state, which are caused in its different parts by different sets of incident forces; and it is similarly by the rhythmical production and compensation of these contrary deviations, that the species continues to live." Hence, to understand the way in which a species is affected by causes which destroy some of its units and favour the multiplication of others, we must consider it as a whole whose units are held together by complex forces that are ever balancing themselves and ever being disturbed—a whole whose moving equilibrium is continually being modified, and through which waves of perturbation are continually being propagated. Thus much premised, let us next call to mind in what way moving equilibria in general are changed. In the first place, the necessary effect wrought by a new incident force falling on any part of an aggregate with balanced motions, is to produce a new motion in the direction of least resistance. In the second place, the new incident force is gradually used up in overcoming the opposing forces, and when it is all expended the opposing forces produce a recoil—a reverse deviation that counter-balances the original deviation. Consequently, to consider whether the moving equilibrium of a species is modified in the same way as moving equilibria in general, is to consider whether, when exposed to a new force, a species yields in the direction of least resistance; and whether, by its thus yielding, there is generated in the species a compensating change in the opposite direction. We shall find that it does both these things.

For what, expressed in mechanical terms, is the effect wrought on a species by some previously-unknown enemy, that kills such of its members as fail in defending themselves? The disappearance of those individuals which meet the destroying forces by the smallest defensive forces, is tantamount to the yielding of the species as a whole at the places where the resistances are the least. Or if by some general influence, such as alteration of climate, the members of a species are subject to any increase of certain external actions that are ever tending to overthrow their equilibria, and which they are ever counter-balancing by the absorption of nutriment, which are the first to die? Those that are least able to generate the internal actions which antagonize these external actions. If the change be an increase of the winter's cold, then such members of the species as have unusual powers of getting food or of digesting food, or such as are by their constitutional aptitude for making fat, furnished with reserve stores of force, available in times of scarcity, or such as have the thickest coats and so lose least heat by radiation, survive; and their survival implies that in each of them the moving equilibrium of functions presents such an adjustment of internal forces, as prevents its overthrow by the modified aggregate of external forces. Conversely, the members that die, are, other things equal, those deficient in the power of meeting the new action by an equivalent counter-action. Thus, in all cases, a species considered as an aggregate in a state of moving equilibrium, has its state changed by the yielding of its fluctuating mass wherever this mass is weakest in the relation to the special forces acting on it. The conclusion is, indeed, a truism. But now, what must follow from the destruction of the least-resisting individuals and survival of the most-resisting individuals? On the moving equilibrium of the species as a whole, existing from generation to generation, the effect of this deviation from the mean state is to produce a compensating deviation. For if all such as are deficient of power in a certain direction are destroyed, what must be the influence on posterity? Had those which are destroyed lived and left offspring, the next generation would have had the same average balance of powers as preceding generations: there would have been a like proportion of individuals less endowed with this power, and individuals more endowed with this power. But the more-endowed individuals being alone left to continue the race, there must result a new generation characterized by a larger average endowment of this power. That is to say, on the moving equilibrium constituted by a species, an action producing change in a given direction, is followed, in the next generation, by a reaction producing an opposite change. Observe, too, that these effects correspond in their degrees of violence. If the alteration of some external factor is so great that it leaves alive only a few individuals, characterized by extreme endowments of the power required to antagonize it; then, in succeeding generations, there is a rapid multiplication of individuals similarly characterized by extreme endowments of this power—the force impressed calls out an equivalent conflicting force. Moreover, the change is temporary where the cause is temporary, and permanent where the cause is permanent. All that are deficient in the needful attribute having been killed off; and the survivors having the needful attribute in a comparatively high degree; there will descend from them, not only some possessing equal amounts of this attribute with themselves, but also some possessing less amounts of it. If the agency which proves fatal to them has not continued in action, such less-endowed individuals will multiply; and the species, after sundry oscillations, will return to its previous mean state. But if this agency be a persistent one, such less

among all its members, one is better adapted than the rest to take advantage of some before-unused agency in the environment, is to say that its moving equilibrium is, in so far, more stably adjusted with respect to the aggregate of surrounding influences. And if, as a consequence, this individual maintains its moving equilibrium when others fail to do so, and produces offspring which do the like—that is, if individuals thus characterized multiply and supplant the rest; there is evidently, as before, a process by which an equilibration between the organism and its environment is effected, not immediately but mediately, through the continuous intercourse between the species as a whole and the environment.

§ 168. Thus we see that indirect equilibration does whatever direct equilibration cannot do. It is scarcely possible too much to emphasize the conclusion, that all these processes by which organisms are re-fitted to their ever-changing environments, must be equilibrations of one kind or other. As authority for this conclusion, we have not simply the universal truth that change of every order is towards equilibrium; but we have also the truth which holds throughout the organic world, that life itself is the maintenance of a moving equilibrium between inner and outer actions—the continuous adjustment of internal relations to external relations; or the maintenance of a correspondence between the forces to which an organism is subject and the forces which it evolves. For if the preservation of life is the preservation of such a moving equilibrium, it becomes a corollary that those changes which enable a species to live under altered conditions, are changes towards equilibrium with the altered conditions.

Hence, all such changes being equilibrations, their differences can be nothing but differences in the ways through which they result. If they are not effected immediately, they must be effected mediately. *A priori*, therefore, we may be certain that all processes of modification which do not come within the class of direct equilibrations, must come within the class of indirect equilibrations.

Examination of the facts confirms this conclusion. The external factors to which a species is exposed, are of two kinds. They are such as act continuously or frequently on the individuals; or they are such as do not act continuously or frequently on the individuals. To a factor which continuously or frequently acts on the individuals, the functions of the individuals re-adjust themselves—there is direct equilibration. While a factor which does not act continuously or frequently on the individuals, acts continuously on the species as a whole—either destroying such of the members as are least capable of resisting it, or fostering such of the members as are most capable of taking advantage of it. And by the abstraction, generation after generation, of those least in equilibrium with the new factor; or by the extra multiplication, generation after generation, of those most in equilibrium with the new factor; the species as a whole is eventually brought into complete equilibrium with the new factor—there is indirect equilibration.

CHAPTER XIII.

THE CO-OPERATION OF THE FACTORS.

§ 169. Thus the phenomena of organic evolution, may be interpreted in the same way as the phenomena of all other evolution. Those universal laws of the re-distribution of matter and motion, to which things in general conform, are conformed to by all living things; whether considered in their individual histories, in their histories as species, or in their aggregate history. However otherwise they may ordinarily be expressed, the truths of development as exhibited in the animal and vegetal kingdoms, prove to be expressible as manifestations of those abstract truths set forth in *First Principles*. Fully to see this, it will be needful for us to contemplate in their *ensemble*, the several processes separately described in the four preceding chapters.

If the forces acting on any aggregate remain the same, the changes produced by them in the aggregate will presently reach a limit, at which the constant outer forces are balanced by the constant inner forces; and thereafter no further metamorphosis will take place. Hence, that there may be continuous changes of structure in organisms, there must be continuous changes in the incident forces. This condition to the evolution of animal and vegetal forms, we find to be fully satisfied. The astronomic, geologic, and meteorologic changes that have been slowly but incessantly going on, and have been increasing in the complexity of their combinations,

balance of functions has not been overthrown. Inevitably, therefore, survival through successive changes of conditions, implies successive adjustments of the balance to the new conditions. This deduction we find to be inductively verified. What is ordinarily called adaptation, is, when translated into mechanical terms, direct equilibration. And that process which, under the name of natural selection, Mr Darwin has shown to be an ever-acting means of fitting the structures of organisms to their circumstances, we find, on analysis, to be expressible in mechanical terms as indirect equilibration.

The actions that are here specified in succession, are in reality simultaneous; and they must be so conceived before organic evolution can be rightly understood. Some aid towards so conceiving them, will be given by the annexed table, representing the co-operation of the factors.

§ 170. Respecting this co-operation of these factors, it remains only to point out their respective shares in producing the total result; and the way in which the proportions of their respective shares vary as evolution progresses.

At first, changes in the amounts and combinations of external inorganic forces, astronomic, geologic, and meteorologic, were the only causes of the successive modifications undergone by organisms; and these changes have continued, and must still continue, to be causes of such modifications. As, however, through the diffusion of organisms, and the consequent differential actions of inorganic forces on them, there arose unlikenesses among organisms, producing varieties, species, genera, orders, classes, &c.; the actions of organisms on one another became new sources of organic modifications. And as fast as types have multiplied, and become more complex; so fast have the mutual actions of organisms come to be more influential factors in their respective evolutions. Until, eventually, as we see exemplified in the human race, they have come to be the chief factors.

Passing from the external causes of change to the internal

- Astronomic changes
- Geologic changes
- Meteorologic changes
  - alter the incidence of inorganic forces.
- Enemies, Competitors, Co-operators, Prey — varying in number
- Enemies, Competitors, Co-operators, Prey — varying in kind
  - alter the incidence of organic forces.
    - on each species: affecting
      - its individuals,
        - immediately through their functions;
          - which, partially in the first generation, and completely in the course of generations, are directly equilibrated with the changed agencies.
          - which have their direct equilibration with the changed agencies, aided by indirect equilibration, through the more frequent survival of those in which the direct equilibration is most rapid.
        - mediately through the aggregate of individuals;
          - positively—by aiding the multiplication of those whose moving equilibria happen to be most congruous with the changed agencies: thus, in the course of generations, indirectly equilibrating certain individuals with them.
          - negatively—by killing those whose moving equilibria are most incongruous with the changed agencies: thus, in the course of generations, indirectly equilibrating each of its surviving individuals with them.
      - its aggregate of individuals,
        - by acting on it in some parts of the habitat more than in others; and thus differentiating the species into local varieties.
        - by acting differently on slightly-unlike individuals in the same locality;
          - and thus causing differentiations of the species into varieties, irrespective of locality.
          - and thus causing modification of the species as a whole, by abstracting a certain class of its units.

processes of change entailed by them, we see that these, too, have varied in their proportions—that which was originally the most important and almost the sole process, becoming gradually less important, if not at last the least important. Always there must have been, and always there must continue to be, a survival of the fittest: natural selection must have been in operation at the outset, and can never cease to operate. While yet organisms had comparatively feeble powers of co-ordinating their actions, and adjusting them to environing actions, natural selection worked almost alone in moulding and re-moulding organisms into fitness for their changing environments; and natural selection has remained almost the sole agency by which plants and inferior orders of animals have been modified and developed. The equilibration of organisms that are comparatively passive, is necessarily effected indirectly, by the action of incident forces on the species as a whole. But along with the gradual evolution of organisms having some activity, there grows up a kind of equilibration that is relatively direct. In proportion as the activity increases, direct equilibration plays a more important part. Until, when the nervo-muscular apparatus becomes greatly developed, and the power of varying the actions to fit the varying requirements becomes considerable, the share taken by direct equilibration rises into co-ordinate importance. We have seen reason to think that as fast as essential faculties multiply, and as fast as the number of organs that co-operate in any given function increases, indirect equilibration through natural selection, becomes less and less capable of producing specific adaptations; and remains fully capable only of maintaining the general fitness of constitution to conditions. Simultaneously, the production of adaptations by direct equilibration, takes the first place—indirect equilibration serving to facilitate it. Until at length, among the civilized human races, the equilibration becomes mainly direct: the action of natural selection being restricted to the destruction of those who are constitutionally too feeble

CHAPTER XIV.

THE CONVERGENCE OF THE EVIDENCES.

§ 171. Of the three classes of evidences that have been assigned, the *à priori*, which we took first, were partly negative, partly positive.

On considering the "General Aspects of the Special-creation-hypothesis," we discovered it to be worthless. Discredited by its origin, and wholly without any basis of observed fact, we found that it was not even a thinkable hypothesis; and while thus intellectually illusive, it turned out on examination to have moral implications quite at variance with the professed beliefs of those who hold it.

Contrariwise, the "General Aspects of the Evolution-hypothesis," begot the stronger faith in it the more nearly they were considered. By its lineage and its kindred, it was found to be as closely allied with the proved truths of modern science, as is the antagonist hypothesis with the proved errors of ancient ignorance. Instead of being a mere pseud-idea, we saw that it admitted of elaboration into a definite conception—so showing its legitimacy as an hypothesis. Instead of positing a purely fictitious process, the process which it alleges, we saw to be one that is actually going on around us. To which add, that morally considered, this hypothesis presents no irreconcilable incongruities.

Thus, even were we without further means of judging, there could be no rational hesitation which of the two views should be entertained.

§ 172. Further means of judging, however, we found to be afforded by bringing the two hypotheses face to face with the general truths established by naturalists. These inductive evidences were dealt with in four chapters.

"The Arguments from Classification" were these. Organisms fall into groups within groups; and this is the arrangement which we see results from evolution, where it is known to take place. Of these groups within groups, the great or primary ones are the most unlike, the sub-groups are less unlike, the sub-sub-groups still less unlike, and so on; and this, too, is a characteristic of groups demonstrably produced by evolution. Moreover, indefiniteness of equivalence among the groups, is common to those which we know have been evolved, and those here supposed to have been evolved. And then there is the further significant fact, that divergent groups are allied through their lowest rather than their highest members—a truth which the hypothesis of evolution implies.

Of "the Arguments from Embryology," the first and most striking is, that when the developments of embryos are traced from their common starting point, and their divergences and re-divergences symbolized by a genealogical tree, there is manifest a general parallelism between the arrangement of its primary, secondary, and tertiary branches, and the arrangement of the divisions and sub-divisions of our classifications—a general parallelism to be anticipated as a result of evolution. Nor do those minor deviations from this general parallelism, which at first sight look like difficulties, fail, on closer observation, to become additional supports; since those traits of a common ancestry which embryology reveals, are, if modifications have resulted from changed conditions, liable to be distorted or disguised in quite different ways and degrees in different lines of descendants

We next considered "the Arguments from Morphol Leaving out those kinships among organisms disclos their developmental metamorphoses, the kinships which adult forms show are profoundly significant. The remar unities of type which are found under such different c nals, are inexplicable except as results of community o scent with non-community of modification. Again, organism analyzed apart, shows us, in the likenesses cha by unlikenesses of its component parts, a peculiarity of s ture that can be ascribed only to the formation of a heterogeneous organism out of a more homogeneous And once more, the habitual existence of rudimentary or homologous with organs that are developed in allied an or plants, while it admits of no other rational interpreta has a satisfactory interpretation given to it by the h thesis of evolution.

Last of the inductive evidences, came "the Arguments Distribution." While the phenomena of distributio Space, prove to be unaccountable as results of designed ad ation of organisms to their habitats, they prove t accountable as results of the competition of species, and spread of the superior into the habitats of the inferior, lowed by the changes which new conditions induce. Th the phenomena of distribution in Time, are so fragmen that no positive conclusion can be drawn from them; ye of them are reconcileable with the hypothesis of evolution, some of them yield it strong support—especially the relationship that exists between the living and ext types of each great geographical area.

In each of these four groups, we thus found several a ments which point to the same conclusion; and the c clusion pointed to by the arguments of any one group, is pointed to by the arguments of all the other groups. coincidence of coincidences, would give to the inducti very high degree of probability, even were it not enfo by deduction.

librium of inner actions corresponding with outer actions, which constitutes the life of an organism, must either be overthrown by a change in the outer actions, or must undergo perturbations that cannot end until there is a re-adjusted balance of functions and correlative adaptation of structures. Wherever the external changes are such as to be continuously or frequently operative on individuals, this direct equilibration must go on.

But where the external changes are either such as are fatal when experienced by the individuals, or such as act on the individuals in ways that do not affect the equilibrium of their functions; then the re-adjustment results through the effects produced on the species as a whole—there is indirect equilibration. By natural selection or survival of the fittest—by the preservation in successive generations of those whose moving equilibria happen to be least at variance with the requirements, there is eventually produced a changed equilibrium completely in harmony with the requirements.

And thus it results that those universal laws of the redistribution of matter and motion, which are conformed to by evolution in general, are conformed to by organic evolution.

§ 174. Even were this the whole of the evidence assignable for the belief that organisms of all orders have been gradually evolved, this belief would have a warrant much higher than that of very many beliefs that are regarded as established. When we see that there are strong *à priori* probabilities in its favour, and wholly adverse to the antagonist hypothesis—when an examination of the facts which naturalists have accumulated, leads us to several groups of inductions which unite in supporting it—and when the characteristics which conspire to show that organic evolution has been going on, prove to be deducible from those universal actions known to work evolution of all other kinds; we have a combination of proofs which might suffice were there no more to be said.

But the evidence is far from exhausted. At the outset o the argument, it was remarked that the *ensemble* of vital phenomena presented by the organic world as a whole, cannot be properly dealt with apart from the *ensemble* of vital phenomena presented by each organism, in the course of its growth, development, and decay. The interpretation of either implies interpretation of the other; since the two are in reality parts of one process. Hence, the validity of any hypothesis respecting the one class of phenomena, may be tested by its congruity with phenomena of the other class. We are now about to pass to the more special phenomena of development, as displayed in the structures and functions of individual organisms. If the hypothesis that plants and animals have been progressively evolved, be true, it must furnish us with keys to these phenomena. We shall find that it does this; and by doing it, gives numberless additional vouchers for its truth.

[*The following letter, originally written for publication in the* North American Review, *but declined by the Editor in pursuance of a general rule, and eventually otherwise published in the United States, I have thought well to append to this first volume of the* Principles of Biology. *I do this because the questions which it discusses are dealt with in this volume; and because the further explanations it furnishes seem needful to prevent misapprehensions.*]

ON ALLEGED "SPONTANEOUS GENERATION," AND ON THE HYPOTHESIS OF PHYSIOLOGICAL UNITS.

The Editor of the North American Review.

SIR,

It is in most cases unwise to notice adverse criticisms. Either they do not admit of answers or the answers may be left to the penetration of readers. When, however, a critic's allegations touch the fundamental propositions of a book, and especially when they appear in a periodical having the position of the *North American Review*, the case is altered. For these reasons the article on "Philosophical Biology," published in your last number, demands from me an attention which ordinary criticisms do not.

It is the more needful for me to notice it, because its two leading objections have the one an actual fairness and the other an apparant fairness; and in the absence of explanations from me, they will be considered as substantiated even by many, or perhaps most, of those who have read the work itself—much more by those who have not read it. That to prevent the spread of misapprehensions I ought to say something, is further shown by the fact that the same two objections have already been made in England—the one by Dr. Child, of Oxford, in his *Essays on Physiological Subjects*, and the other by a writer in the *Westminster Review* for July, 1865.

In the note to which your reviewer refers, I have, as he says, tacitly repudiated the belief in "spontaneous generation;" and that I have done this in such a way as to leave open the door for the interpretation given by him is true. Indeed the fact that Dr. Child, whose criticism is a sympathetic one, puts the same construction on this note, proves that your reviewer has but drawn what seems to be a necessary inference. Nevertheless, the inference is one which I did not intend to be drawn.

In explanation, let me at the outset remark that I am placed at a disadvantage in having had to omit that part of the System of Philosophy which deals with Inorganic Evolution. In the orginal programme will be found a parenthetic reference to this omitted part, which should, as there stated, precede the *Principles of Biology*.

Two volumes are missing. The closing chapter of t
it written, would deal with the evolution of orgal
step preceding the evolution of living forms. Hab
with me in thought the contents of this unwritten c
in some cases, expressed myself as though the read
him; and have thus rendered some of my state
misconstructions. Apart from this, however, the ex
apparent inconsistency is very simple, if not very obvi
place, I do not believe in the "spontaneous generat
alleged, and referred to in the note; and so little h
in thought this alleged "spontaneous generation"
believe, with the generation by evolution which I do l
repudiation of the one never occurred to me as liable to
pudiation of the other. That creatures having *quite speci*
evolved in the course of a few hours, without antecec
to determine their specific forms, is to me incredible.
established truths of Biology, but the established tr
in general, negative the supposition that organisms
tures definite enough to identify them as belonging to
and species, can be produced in the absence of germ
antecedent organisms of the same genera and species
suddenly be imposed on simple protoplasm the orga
constitutes it a *Paramæcium*, I see no reason why ani
complexity, or indeed of any complexity, may not
after the same manner. In brief, I do not accept the
as exemplifying Evolution, because they imply someti
beyond that which Evolution, as I understand it, ca
the second place, my disbelief extends not only to th
of "spontaneous generation," but to every case akin
very conception of spontaneity is wholly incongruous
ception of Evolution. For this reason I regard as ob
Darwin's phrase "spontaneous variation" (as indeed h
and I have sought to show that there are always assig
variation. No form of Evolution, inorganic or or
spontaneous; but in every instance the antecedent f
adequate in their quantities, kinds, and distribution
observed effects. Neither the alleged cases of "spo
ration," nor any imaginable cases in the least allied
this requirement.

If, accepting these alleged cases of "spontaneous
had assumed, as your reviewer seems to do, that t
organic life commenced in an analogous way; then, in
have left myself open to a fatal criticism. This su
taneous generation" habitually occurs in menstrua
either organic matter, or matter originally derived fr
and such organic matter, proceeding in all known cas
isms of a higher kind, implies the pre-existence o

another. And the vagueness, the inconstancy, the vari ciable structure, displayed by the simplest of living t now see them, are characters (or absences of characte the hypothesis of Evolution, must have been still m when, asat first, no "forms," no "types," no "specific been moulded. That "absolute commencement of or the globe," which the reviewer says I "cannot evade th of," I distinctly deny. The affirmation of universal ev itself the negation of an "absolute commencement" Construed in terms of evolution, every kind of being is a product of modifications wrought by insensible grad pre-existing kind of being; and this holds as fully of th "commencement of organic life" as of all subsequent d of organic life. It is no more needful to suppose an commencement of organic life" or a "first organism, needful to suppose an absolute commencement of soci first social organism. The assumption of such a nece last case, made by early speculators with their theories contracts" and the like, is disproved by the facts; and so far as they are ascertained, disprove the assumptio necessity in the first case. That organic matter was n all at once, but was reached through steps, we are wel in believing by the experiences of chemists. Organic produced in the laboratory by what we may literally c *evolution*. Chemists find themselves unable to form the combinations directly from their elements; but they succe ing them indirectly, by successive modifications of simpl tions. In some binary compound, one element of whic in several equivalents, a change is made by substituting these equivalents an equivalent of some other element; a a ternary compound. Then another of the equivalents and so on. For instance, beginning with ammonia, N H form is obtained by replacing one of the atoms of by an atom of methyl, so producing methyl-amine, N and then, under the further action of methyl, en further substitution, there is reached the still more com stance dimethyl-amine, N (C H,) (C H,) H. And in highly complex substances are eventually built up. characteristic of their method is no less significant. plex compounds are employed to generate, by their a one another, a compound of still greater complexit heterogeneous molecules of one stage, become parents cule a stage higher in heterogeneity. Thus, having bui acid out of its elements, and having by the process of subs scribed above, changed the acetic acid into propionic acid onic into butyric, of which the formula is { C (C H,) (C / C O (H O) this complex compound, by operating on anotner complex compound, such as the dimethyl-amine named above, generates one of still greater complexity, butyrate of dimethyl-amine $\left\{ \begin{matrix} C\,(C\,H)\,(C\,H_3)\,H \\ C\,O\,(H\,O) \end{matrix} \right\} N\,(C\,H_3)\,(C\,H_3)\,H$. See, then, the remarkable parallelism. The progress towards higher types of organic molecules is effected by modifications upon modifications; as throughout Evolution in general. Each of these modifications is a change of the molecule into equilibrium with its environment—an adaptation, as it were, to new surrounding conditions to which it is subjected; as throughout Evolution in general. Larger, or more integrated, aggregates (for compound molecules are such) are successively generated; as throughout Evolution in general. More complex or heterogeneous aggregates are so made to arise, one out of another; as throughout Evolution in general. A geometrically-increasing multitude of these larger and more complex aggregates so produced, at the same time results; as throughout Evolution in general. And it is by the action of the successively higher forms on one another, joined with the action of environing conditions, that the highest forms are reached; as throughout Evolution in general.

When we thus see the identity of method at the two extremes—when we see that the general laws of evolution, as they are exemplified in known organisms, have been unconsciously conformed to by chemists in the artificial evolution of organic matter; we can scarcely doubt that these laws were conformed to in the natural evolution of organic matter, and afterwards in the evolution of the simplest organic forms. In the early world, as in the modern laboratory, inferior types of organic substances, by their mutual actions under fit conditions, evolved the superior types of organic substances, ending in organizable protoplasm. And it can hardly be doubted that the shaping of organizable protoplasm, which is a substance modifiable in multitudinous ways with extreme facility, went on after the same manner. As I learn from one of our first chemists, Prof. Frankland, *protein* is capable of existing under probably at least a thousand isomeric forms; and, as we shall presently see, it is capable of forming, with itself and other elements, substances yet more intricate in composition, that are practically infinite in their varieties of kind. Exposed to those innumerable modifications of conditions which the Earth's surface afforded, here in amount of light, there in amount of heat, and elsewhere in the mineral quality of its aqueous medium, this extremely changeable substance must have undergone now one, now another, of its countless metamorphoses. And to the mutual influences of its metamorphic forms under favouring conditions, we may ascribe the production of the still more composite, still more sensitive, still more variously-changeable portions of organic matter, which, in masses more minute and simpler than existing *Protozoa*, displayed actions verging little by little into those called vital—actions which protein itself exhibits in a certain degree, and which the lowest known living things exhibit only in a greater degree. Thus, setting out with inductions from the experiences of organic chemists at the one extreme, and with inductions from the observations of biologists at the other extreme, we are enabled deductively to bridge the interval—are enabled to conceive how organic compounds were evolved, and how, by a continuance of the process, the nascent life displayed in these became gradually more pronounced. And this it is which has to be explained, and which the alleged cases of "spontaneous generation" would not, were they substantiated, help us in the least to explain.

It is thus manifest, I think, that I have not fallen into the alleged inconsistency. Nevertheless, I admit that your reviewer was justified in inferring this inconsistency; and I take blame to myself for not having seen that the statement, as I have left it, is open to misconstruction.

I pass now to the second allegation—that in ascribing to certain specific molecules, which I have called "physiological units," the aptitude to build themselves into the structure of the organism to which they are peculiar, I have abandoned my own principle, and have assumed something beyond the re-distribution of Matter and Motion. As put by the reviewer, his case appears to be well made out; and that he is not altogether unwarranted in so putting it, may be admitted. Nevertheless, there does not in reality exist the supposed incongruity.

Before attempting to make clear the adequacy of the conception which I am said to have tacitly abandoned as insufficient, let me remove that excess of improbability the reviewer gives to it, by the extremely-restricted meaning with which he uses the word mechanical. In discussing a proposition of mine he says:—

"He then cites certain remarks of Mr. Paget on the permanent effects wrought in the blood by the poison of scarlatina and small-pox, as justifying the belief that such a 'power' exists, and attributes the repair of a wasted tissue to 'forces analogous to those by which a crystal reproduces its lost apex.' (Neither of which phenomena, however, is explicable by mechanical causes.)"

Were it not for the deliberation with which this last statement is made, I should take it for a slip of the pen. As it is, however, I have no course left but to suppose the reviewer unaware of the fact that molecular actions of all kinds are now not only conceived as mechanical actions, but that calculations based on this conception of them, bring out the results that correspond with observation. There is no kind of re-arrangement among molecules (crystallization being one) which the modern physicist does not think of,

representable in terms of the mechanical hypothesis. Every physicist will endorse the proposition that in each aggregate there tends to establish itself an equilibrium between the forces exercised by all the units upon each and by each upon all. Even in masses of substance so rigid as iron and glass, there goes on a molecular re-arrangement, slow or rapid according as circumstances facilitate, which ends only when there is a complete balance between the actions of the parts on the whole and the actions of the whole on the parts: the implication being that every change in the form or size of the whole, necessitates some redistribution of the parts. And though in cases like these, there occurs only a polar re-arrangement of the molecules, without changes in the molecules themselves; yet where, as often happens, there is a passage from the colloid to the crystalloid state, a change of constitution occurs in the molecules themselves. These truths are not limited to inorganic matter: they unquestionably hold of organic matter. As certainly as molecules of alum have a form of equilibrium, the octahedron, into which they fall when the temperature of their solvent allows them to aggregate, so certainly must organic molecules of each kind, no matter how complex, have a form of equilibrium in which, when they aggregate, their complex forces are balanced—a form far less rigid and definite, for the reason that they have far less definite polarities, are far more unstable, and have their tendencies more easily modified by environing conditions. Equally certain is it that the special molecules having a special organic structure as their form of equilibrium, must be reacted upon by the total forces of this organic structure; and that, if environing actions lead to any change in this organic structure, these special molecules, or physiological units, subject to a changed distribution of the total forces acting upon them will undergo modification—modification which their extreme plasticity will render easy. By this action and reaction I conceive the physiological units peculiar to each kind of organism, to have been moulded along with the organism itself. Setting out with the stage in which protein in minute aggregates, took on those simplest differentiations which fitted it for differently-conditioned parts of its medium, there must have unceasingly gone on perpetual re-adjustments of balance between aggregates and their units—actions and reactions of the two, in which the units tended ever to establish the typical form produced by actions and reactions in all antecedent generations, while the aggregate, if changed in form by change of surrounding conditions, tended ever to impress on the units a corresponding change of polarity, causing them in the next generation to reproduce the changed form—their new form of equilibrium.

This is the conception which I have sought to convey, though it seems unsuccessfully, in the *Principles of Biology*; and which I have there used to interpret the many involved and mysterious

ing it has been pointed out. He knows that I have repeatedly and emphatically asserted that our conceptions of Matter and Motion are but symbols of an Unknowable Reality; that this Reality cannot be that which we symbolize it to be; and that as manifested beyond consciousness under the forms of Matter and Motion, it is the same as that which, in consciousness, is manifested as Feeling and Thought. Yet he continues to describe me as reducing everything to dead mechanism. If his statement on pp. 383-4 has any meaning at all, it means that there exists some "force operating *ab extra*," some "external power" distinguished by him as "mechanical," which is not included in that immanent force of which the universe is a manifestation; though whence it comes he does not tell us. This conception he speaks of as though it were mine; making it seem that I ascribe the moulding of organisms to the action of this "mechanical" "external power," which is distinct from the Inscrutable Cause of things. Yet he either knows, or has ample means of knowing, that I deny every such second cause: indeed he has himself classed me as an opponent of dualism. I recognize no forces within the organism, or without the organism, but the variously-conditioned modes of the universal immanent force; and the whole process of organic evolution is everywhere attributed by me to the co-operation of its variously-conditioned modes, internal and external. That this has been all along my general view, is clearly shown in the closing paragraph of *First Principles*, where I have said—

"A Power of which the nature remains for ever inconceivable, and to which no limits in Time or Space can be imagined, works in us certain effects. These effects have certain likenesses of kind, the most general of which we class together under the names of Matter, Motion, and Force; and between these effects there are likenesses of connection, the most constant of which we class as laws of the highest certainty. Analysis reduces these several kinds of effect to one kind of effect; and these several kinds of uniformity to one kind of uniformity. And the highest achievement of Science is the interpretation of all orders of phenomena, as differently-conditioned manifestations of this one kind of effect, under differently-conditioned modes of this one kind of uniformity. But when Science has done this, it has done nothing more than systematise our experience; and has in no degree extended the limits of our experience. We can say no more than before, whether the uniformities are as absolutely necessary, as they have become to our thought relatively necessary. The utmost possibility for us, is an interpretation of the process of things as it presents itself to our limited consciousness; but how this process is related to the actual process, we are unable to conceive, much less to know. Similarly, it must be remembered that while the connection between the phenomenal order and the ontological order is for ever inscrutable; so is the connection between the conditioned forms of being and the unconditioned form of being for ever inscrutable. The interpretation of all phenomena in terms of Matter, Motion, and Force, is nothing more than the reduction of our complex symbols of thought, to the simplest symbols; and when the equation has been brought to its lowest terms the symbols remain symbols still. Hence the reasonings contained in the foregoing pages, afford no support to either of the antagonist hypotheses respecting the ultimate nature of

[redacted]

things. Their implications are no more materialistic than they are spiritualistic; and no more spiritualistic than they are materialistic. Any argument which is apparently furnished to either hypothesis, is neutralized by as good an argument furnished to the other. The Materialist, seeing it to be a necessary deduction from the law of correlation, that what exists in consciousness under the form of feeling, is transformable into an equivalent of mechanical motion, and by consequence into equivalents of all the other forces which matter exhibits; may consider it therefore demonstrated that the phenomena of consciousness are material phenomena. But the Spiritualist, setting out with the same data, may argue with equal cogency, that if the forces displayed by matter are cognizable only under the shape of those equivalent amounts of consciousness which they produce, it is to be inferred that these forces, when existing out of consciousness, are of the same intrinsic nature as when existing in consciousness; and that so is justified the spiritualistic conception of the external world, as consisting of something essentially identical with what we call mind. Manifestly, the establishment of correlation and equivalence between the forces of the outer and the inner worlds, may be used to assimilate either to the other; according as we set out with one or other term. But he who rightly interprets the doctrine contained in this work, will see that neither of these terms can be taken as ultimate. He will see that though the relation of subject and object renders necessary to us these antithetical conceptions of Spirit and Matter; the one is no less than the other to be regarded as but a sign of the Unknown Reality which underlies both."

This is the conception which your reviewer continues to speak of as "mechanical" and "mechanist;" without giving his readers any suspicion of the qualified sense in which only these words can be applied. If he thinks that by doing this he has represented the conception with fairness, or with any approach to fairness, I cannot agree with him.

I am, Sir,

Yours, &c.,

HERBERT SPENCER.

London, December 5, 1868.

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