SUMMARY AND CONCLUSION

All the phenomena of heredity depend on minute vital units which we have called 'biophors,' and of which living matter is composed: these are capable of assimilation, growth, and multiplication by division. We are unacquainted with the lowest conceivable organisms, and do not even know if they still exist. But they must at any rate have done so at some time or other, in the form of single biophors, in which multiplication and transmission occurred together, no special mechanism for the purposes of heredity being present. A higher order of beings would then have been constituted by those organisms which were composed of a large number of similar biophors. Of these also we have no actual knowledge based on observation, but must suppose that they too required no special apparatus for the processes of transmission; for a reproduction by binary fission must result in two perfectly corresponding halves, each containing similar biophors, and each of which, simply by the multiplication of these units, is able to give rise to a complete organism exactly like the parent.

This simple form of transmission must have become modified when the biophors underwent differentiation in connection with a division of labour, and became combined in various ways to form the body of the organism. These two kinds of hypothetical beings might be respectively distinguished as homo-biophorids and hetero-biophorids. Not only might a firmer cortex and softer internal substance be present in the latter, but a differentiation into anterior, posterior, dorsal, and ventral regions might occur; several layers of the body substance, differing structurally and functionally from one another, might also be developed, together with motile and non-motile processes — such as flagella, cilia, spines, and hooks, — like those present amongst the Infusoria; and there might, moreover, be a permanent aperture in the firmer outer layer through which solid food passed into the interior, and so on.

When the body thus became constructed, in a more or less complex manner, of various kinds of biophors arranged in a definite manner, simple binary fission no longer sufficed for the transmission of the characters of the parent to the offspring. If the parts situated in the anterior, posterior, right, left, dorsal, and ventral regions differed from one another, all the elements — *i.e.*, all the kinds and groups of biophors — could not, by any method of halving, be transmitted to both the offspring resulting by division so that they could develop by mere growth into an organism resembling the parent. Special means must then have been adopted to render such a completion and consequent perfect transmission possible; *and this was attained by the formation of a nucleus.*

We may, with de Vries, regard the cell-nucleus as having originally served merely for the storage of reserve biophors, which were destined to become doubled on the division of the organism, each half rendering the completion to an entire individual possible when those kinds of biophors which were wanting were transferred to it. Subsequently — that is, in the multicellular organs possessing highly differentiated cells — the nucleus took on other functions, which regulated the specific activity of the cell, though it still retained biophors capable of supplying the characters of the cells which were still wanting, and therefore still served as the bearer of the biophors controlling the character of the cell.

If, therefore, a special apparatus for transmission became necessary in the hetero-biophorids or unicellular organisms, and appeared in the 'cell' in the form of a '*nucleus*,' it must have become still more complex on the introduction of the remarkable process of amphimixis, which, in its simplest and original form, consists in the complete fusion of two organisms in such a manner that nucleus unites with nucleus and cell-body with cell-body. In the higher unicellular organisms this process is in most cases restricted to the fusion of the nuclei, half the nucleus of one animal uniting with half that of another. The process of division shows that the nucleus has a structure precisely analogous to that of the nucleus in multicellular organisms; we may therefore assume that the hereditary substance here likewise consists of several equivalent groups of biophors, constituting 'nuclear rods' or 'idants,' each of which contains all the kinds of biophors of the organism, though they deviate slightly from one another in their composition, as they correspond to individual variations. Half the idants of two individuals become united in the process of amphimixis, and thus a fresh intermixture of individual characters results.

The apparatus for transmission in those multicellular organisms in which the cells have undergone a division of labour, is essentially similar to that seen in unicellular beings; although, in correspondence with the greater complexity of their structure, it is more complicated. As the process of amphimixis occurs in them also, and the fusion of highly-differentiated multicellular individuals seems only to be possible by a temporary return to the unicellular condition, we find that the so-called 'sexual reproduction,' which is of general occurrence amongst them, consists in all the primary constituents ('Anlagen') of the entire organism being collected together in the nuclear matter of a single reproductive cell. Two kinds of such cells, which are differently equipped, and mutually attract one another, then unite in the process of amphimixis, and constitute what we are accustomed to call the 'fertilised egg-cell,' which contains the combined hereditary substances of two individuals.

According to our view, this hereditary substance of the multicellular organisms consists of three orders of vital units, the lowest of which is constituted by the biophors. In the unicellular forms a more or less polymorphic mass of biophors, having a definite arrangement, constitutes the individual nuclear rods or idants, several of these making up the hereditary substance of the nucleus which controls the cells; and similarly in these higher forms, groups of biophors, arranged in a certain order, constitute the primary constituents of the individual cells of the body, and together form the second order of vital units,— the cell-determinants,— or simply, the '*determinants*.'

The histological character of every cell in a multicellular organism, including its rate and mode of division, is controlled by such a determinant. The germ-plasm does not, however, contain a special determinant for every cell; but cells of a similar kind, when, like the blood-cells, they are not localised, may be represented by a single determinant in the germ-plasm. On the other hand, every cell, or group of cells, which *is to remain* *independently variable*, must be represented in the germ-plasm by a special determinant. Were this not the case, the cell in question could only vary in common with other cells which are controlled by the same determinant.

The germ-cell of a species must contain as many determinants as the organism has cells or groups of cells which are independently variable from the germ onwards, and these determinants must have a definite mutual arrangement in the germ-plasm, and must therefore constitute a definitely limited aggregate, or higher vital unit, the '*id*.'

From the facts of sexual reproduction and heredity we must conclude that the germ-plasm contains many ids, and not a single one only. The formation of hybrids proves that the two parents together transmit all their specific characters, so that in the process of fertilisation each contributes a hereditary substance which contains the primary constituents of all parts of the organism, — that is, all the determinants required for building up a new individual. The hereditary substance becomes halved at the final stage of development of the germ-cells, and consequently all the determinants must previously have been grouped into at least two ids. But it is very probable that many more ids are usually present, and that in many cases their number far exceeds a hundred.

It cannot be stated with certainty which portions of the elements of the germ-plasm observable in the nucleus of the ovum correspond to ids, though it is probable that only parts of, and not the entire 'chromosomes,' are to be regarded as such. Until this point can be definitely decided, our further detailed deductions will be based on the view that the nuclear rods (chromosomes) are aggregates of ids, which we speak of as '*idants*.' In a certain sense, the latter are also vital units, for they grow and multiply by division; and the combination of ids contained in them, although not a permanent one, persists for some time.

The '*germ-plasm*,' or hereditary substance of the Metazoa and Metaphyta, therefore, consists of a larger or smaller number of idants, which in turn are composed of ids; each id has a definite and special architecture, as it is composed of determinants, each of which plays a perfectly definite part in development.

The development of the primary constituents, contained in the germ-plasm of the reproductive cell, takes place in the course of the cell-divisions to which the ontogeny of a multicellular organism is due, in which process all the ids behave in an exactly similar manner. In the first cell-division every id divides into two halves, each of which contains only half the entire number of determinants; and this process of disintegration is repeated at every subsequent cell-division, so that the ids of the following ontogenetic stages gradually become poorer as regards the diversity of their determinants, until they finally contain only a single kind.

Each cell in every stage is in all cases controlled by only *one* kind of determinant, but several of the same kind may be contained in the id; and the 'control' of the cell is effected by the disintegration of the determinants into biophors, which penetrate through the nuclear membrane into the cell-body; and there, according to definite forces and laws of which we are ignorant, bring about the histological differentiation of the cell, by multiplying more rapidly at the expense of those biophors already forming the cell-body. Each determinant must become 'ripe,' and undergo disintegration into its biophors, at a definite time or at a certain stage of ontogeny. The rest of the determinants in the id of a cell, which are destined for subsequent stages, remain intact, and have therefore no effect on the control of the cell; but the mode of their arrangement in the id, and the special rate of multiplication of each kind, determine the nature of the next nuclear division — that is, as to which determinants are to be distributed to one daughter-cell, and which to the other. The histological nature of these two cells, as well as the control of their successors, is determined by this division; and thus the distribution of the primary constituents contained in the germ-plasm is effected by the architecture of the id, which is at first of a definite kind, but afterwards undergoes continual and systematic changes in consequence of the uneven rate of multiplication and gradual disintegration of the ids.

The apparatus for cell-division is only of secondary importance in the process; its chief part, the 'centrosome,' like the hereditary substance, is derived from the parental germ-cell or cells, but only constitutes the mechanism for the division of the nucleus and cell, and contains no 'primary constituents.' The rate of the cell-divisions cannot, moreover, be determined by the centrosome, although it produces the required stimulus: the apparatus for division is set in motion by the cell, which is controlled by the idioplasm. Were this not the case, the nuclear matter could not be the hereditary substance, for most of the hereditary characters of a species are due in a less degree to the differentiation of individual cells than to the number and grouping of the cells of which a certain organ or entire part of the body consists; these, however, again depend on the mode and rate of cell-division.

The processes occurring in the idioplasm which direct the development of the organism from the ovum — or to speak in more general terms, from one cell, the germ-cell, — do not in themselves furnish an explanation of a series of phenomena which are in part directly connected with the ontogeny, or else result from it sooner or later: the phenomena of *regeneration*, *gemmation*, and *fission*, and the *formation of new germ-cells*, all require special supplementary hypotheses.

The simplest cases of *regeneration* are due to the fully formed tissue, consisting of similar cells, always containing a reserve of young cells, which are capable of replacing a normal or abnormal loss. This, however, is insufficient in the more complex cases, in which entire parts of the body, such as the tail or the limbs, are regenerated when they have been forcibly removed. We must here assume that the cells of the parts which are capable of regeneration contain 'supplementary determinants' in addition to those which control them, and that these are the primary constituents of the parts which are to be formed anew in the process of regeneration. They are supplied to certain parts of the body at an earlier ontogenetic stage in the form of 'inactive accessory idioplasm,' and only become active when the opposition to growth has been removed in consequence of the loss of the part in question. The equipment of a cell of any part with supplementary determinants presupposes a greater complexity in their distribution, in correspondence with the greater complexity in structure of the part; and thus the capacity for regeneration is limited, for a part can no longer be provided with an apparatus for regeneration when its structure is too complicated. The ordinary assumption that the regenerative 'force' decreases as the complexity in structure increases, is therefore to a certain extent true, but not if it implies the existence of a special force which provides for regeneration, and which always diminishes in correspondence with the degree of organisation. Even if we imagine this 'force' to be a mechanico-physiological one, it could not be considered as a *primary* quality of the organism, and to some extent the inevitable result of life itself, but must be looked upon as an adaptation.

Reproduction by fission is closely connected with regeneration; it presupposes the existence of a similar apparatus in the idioplasm, which, however, has in most cases reached a higher stage of development; fission must have arisen phyletically from regeneration.

The origin of multiplication by *gemmation*, and the phenomena exhibited by this form of reproduction, are different from those concerned in fission. In plants and Cœlenterates, gemmation originates in one cell, which must consequently contain a combination of all the determinants of the species closely resembling that existing in the fertilised ovum. In the Polyzoa, however, this process does not originate in one cell, but in at least two, and probably more, belonging to two different layers of cells (germinal layers) of the body; and in Tunicata, again, the material for the bud is produced from all three germinal layers.

The first of these forms of budding must be primarily due to the admixture of 'unalterable' ('gebundenem') germ-plasm to certain series of cells in ontogeny in the form of *inactive 'accessory idioplasm,'* or *'blastogenic' idioplasm* ('Knospungs-Idioplasma'). In plants this is contained in the apical cells; and in hydroid polypes, in the cells of the ectoderm.

In the second group of animals mentioned above, we must assume that the 'blastogenic' germ-plasm becomes disintegrated into two groups of determinants at an early ontogenetic stage, and that each of these is passed on in an 'unalterable' condition, through various generations of cells, until the time and place of its activity are reached.

In the third group, the inactive 'blastogenic' idioplasm divides into three groups of determinants, one of which passes into the ectoderm, the second into certain cell-series of the mesoderm, and the third into others in the endoderm, until they reach the part in which they have to become active.

Gemmation must have originated phyletically by a doubling of the germ-plasm taking place in the fertilised egg, so that one half remained inactive, and was then either passed on as inactive 'blastogenic' germ-plasm, or else became divided up in the course of ontogeny into groups, which were passed separately to the same region, viz., that of the bud.

In all cases in which the power of budding was permanently retained by the species, the occurrence of this process of doubling of the germ-plasm seems to have persisted through the ontogenetic stages from an early period; for we find that the individuals arising by gemmation very frequently vary independently of one another, and often even to a great extent. But independent variation from the germ onwards implies the existence of special determinants in the 'blastogenic' germ-plasm. Medusæ could never have been produced from polypes by budding if independently variable determinants of the buds had not been present in the germ of the fertilised ovum. We therefore assume that *two kinds of germ-plasm exist in those species in which alternation of generations occurs*, both of which are present in the egg-cell as well as in the bud, though only one of them is active at a time and controls ontogeny, while the other remains inactive. The alternating activity of these two germ-plasms causes the alternation of generations.

The *formation of germ-cells* is brought about by the occurrence of similar processes in the idioplasm to those which cause gemmation. One part of the germ-plasm contained in the fertilised egg-cell remains inactive and 'unalterable,'— that is, it does not immediately become disintegrated into groups, but is passed on in the form of accessory idioplasm to certain series of cells in ontogeny, and thus reaches the parts in which germ-cells are to be formed. Thus the whole of the parental germ-plasm, with all its determinants, forms the foundation of the germ-cells which will give rise to the next generation, and the extremely accurate and detailed transmission of parental characters to the offspring is thereby rendered comprehensible.

In multicellular plants and animals, the germ-plasm becomes more complex in consequence of *sexual reproduction*, in which process the ids of two different individuals, the parents, are accumulated in the fertilised egg-cell every time amphimixis occurs. This has caused the occurrence of the 'reducing division,' which accompanies the formation of male and female germ-cells, and results in the number of ids and idants being reduced to the half. The reduction is important in elucidating the phenomena of heredity in forms which are reproduced sexually, for the ids of a germ-plasm are not by any means all alike, but differ to the same relative extent as do the corresponding individuals. As the reduction does not always occur in the same way, and the resulting halves contain different idants on different occasions, and these fall to the share of individual germ-cells, it is possible for the germ-cells of one individual to contain very different combinations of idants. This results in the *dissimilarity* between the offspring of the same parents, — or, to express it in more general terms, in the extreme diversity as regards the intermixture of individual differences.

During the development of a new individual from the fertilised egg-cell, the ontogeny is directed by the ids of the two parents which constitute the germ-plasm. Structures intermediate between those of the parents thus frequently arise — *but only* when perfectly homologous ids are opposed to one another, and have a similar 'controlling force.' This force depends not only on the similar rate of multiplication of the biophors transmitted by the controlling determinants into the cell-body, and on the suppression of those already present, but also on the number of precisely similar determinants derived from each parent. The larger the number of 'homodynamous' determinants, the greater is their controlling effect on the cell; and if a larger number of homodynamous determinants are opposed to fewer heterodynamous determinants of the other parent, the former gain the victory. The preponderance of one of the parents in transmission is thus rendered comprehensible, whether it concerns individual parts or the entire organism.

The type of the child is determined by the paternal and maternal ids contained in the corresponding germ-cells meeting together in the process of fertilisation, and *the blending of parental and ancestral characters is thus predetermined*, and cannot become essentially modified by subsequent influences. The facts relating to identical twins and to plant-hybrids prove that this is so. In the latter, the individuals produced by crossing two constant species display as constant an intermixture of characters as would be the case if they constituted a natural species. The ids of each species must be looked upon as perfectly homodynamous as regards the specific characters; two distinct groups of homodynamous ids are opposed to one another, and the preponderance of one or other parental group in any particular part of the plant depends on the presence of a larger number of homodynamous determinants representing the part in question, and on their possession of a greater controlling force.

Reversion to grandparents and great-grandparents, or to uncles and aunts, may be accounted for by the fact that, in the first place, the idants and ids are not formed anew in the germ-plasm of the parents, but are derived from the grandparents; and, secondly, that the combination of ids contained in the individual germ-cells of the parent becomes very diversified in consequence of the 'reducing division.' The usually accepted assumption of breeders that one-fourth of the 'blood' of the grandchild is derived from each of the four grandparents, and one-eighth from each of the eight great-grandparents, is therefore inaccurate. The number of ids of any particular ancestor which are contained in the germ-plasm of a ripe germ-cell depends entirely on the manner in which the reducing division occurs; and, under certain circumstances, a germ-cell might presumably contain half the entire number of ids of one grandparent, and none of those of the other three. The larger the number of ids derived from an ancestor, the greater is the probability that some of the characters of this ancestor will appear in the descendant; but this depends on the force of the ids of the other parent, which comes into play when amphimixis takes place, and also on whether the ids derived from this ancestor are the dominant ones which determined his 'type' ('Bild').

Reversion to an ancestor must consequently always occur when, in consequence of the 'reducing division,' the ids determining the type of this ancestor reach a particular germ-cell of the individual in question, — if they are not opposed by a stronger group of ids derived from the other parent in the process of amphimixis. This holds good for each individual part of the offspring, as well as for the entire organism, for the number of homodynamous determinants may be, and generally is, different in the various parts, — at any rate in the case of the *individual* differences between human beings.

From this theory, it could be predicted that hybrid-plants fertilised with their own pollen must produce very variable offspring, and that individuals of these hybrids must, moreover, revert to one or other of the ancestral species: both these statements are borne out by fact.

Although *reversion to more remote ancestors* is also brought about by the same factors, — viz., the 'reducing division' and amphimixis, — it requires further elucidation. The theory of selection requires that only a majority, and not *all*, the determinants of a part which is to be modified shall undergo a corresponding change. Old unmodified determinants of various parts are therefore retained in the germ-plasm of a species, and can only be removed from it very gradually by fortuitous 'reducing divisions.' This renders reversion to the characters of very remote ancestors *possible*; its *occurrence*, however, depends upon the reducing division and amphimixis taking place in a favourable manner. If the reduction causes similar groups of ancestral determinants to be brought together in *several* ids, and this germ-plasm, in the process of amphimixis, unites with that of another germ-cell, which also contains similar ancestral determinants in *several* ids, these may gain the victory over the modern determinants in the struggle of the ids during ontogeny. This, however, will chiefly depend on the kind and strength of the modern determinants which are opposed to them; and thus reversion to ancestral characters occurs very frequently in crosses between races (pigeons) and species (mules), in which the modern determinants are heterodynamous; — they do not co-operate, and their forces counteract one another, while the ancestral determinants are similar and their forces cumulative.

Numerous phenomena of reversion in plants and animals may be explained in a very simple manner on these principles, and from this point of view it is also possible to understand that form of reversion which occurs in gemmation and parthenogenesis. The more remote the ancestors to the characters of which reversion occurs, the more rarely will it take place. Reversion to the three-toed ancestors of the horse, for instance, is of extremely rare occurrence, for it is due to a retention of the ancestral determinants in question — which have certainly disappeared from all the ids in the germ-plasm of most existing horses — in single individuals of certain series of generations, and to the chance of the coming together of two germ-cells containing such ancestral determinants.

The remarkable phenomenon of *dimorphism*, which has been introduced so extensively — more especially into the animal kingdom — by means of sexual reproduction, must be due to the presence in the idioplasm of *double determinants* for all those cells, groups of cells, and entire organisms, which are capable of taking on a male and female form. But only one half of such a double determinant remains inactive, while the other becomes active. The sexual differentiation of the germ-cells must thus be due to the presence of spermatogenetic and oogenetic double determinants; and even all the secondary sexual characters must be traced to a similar origin in the idioplasm. The corresponding double determinants are contained not only in the germ-plasm, but are passed on through the cell-stages of ontogeny to that part of the body in which the two characters become separated from one another. One of the determinants then becomes active, its twin half remaining in an inactive condition in the nucleus of a somatic cell, and under certain circumstances becoming active subsequently. This, however, only occurs exceptionally, in such cases as that in which a female animal (*e.g.*, a hen or duck) develops male characters in consequence of castration. Hermaphrodite bees, in which the whole body consists of the most wonderful intermixture of male and female parts, furnishes an instructive proof of the presence of both kinds of characters in all parts of the body, and consequently of the truth of the assumption of double determinants.

Double determinants not only occur individually, but entire *groups* of male and female determinants are opposed to one another, and these are just as dependent on one another as are the two halves of the individual double determinant, one of which always remains inactive when the other becomes active. These groups may be very dissimilar; in many cases (*e.g.*, the olfactory organs of male crustaceans and the ornamental feathers of male birds) the male group contains many more individual determinants than the female. One half of the double group may also become degenerated, so that the corresponding organ (*e.g.*, the wing in many female butterflies) disappears in one sex.

The number of double determinants reaches its highest limit when the two sexes differ completely from one another in all their parts, as is the case in *Bonellia viridis;* even then, however, a number of single determinants may still be present, if, as in this case, the larval stage is similar in both sexes.

The assumption of double determinants is also able to throw some light upon certain enigmatical phenomena of heredity exhibited by human beings. It has long been known that *hæmophilia* occurs in men only, but is transmitted by women. If we assume that the *visible* sexual differences, as well as those existing in the system which we are unable actually to recognise, are due to the presence of double determinants, the peculiar limitation of this uncommon disease to one sex is explained. The disease, like a secondary sexual character, is only transmitted to the sex in which it first appeared, *for this half of the double determinants of the 'mesoblast germ' has alone been modified by the disease.*

The *sexual polymorphism* exhibited by certain butterflies may also be explained by assuming the presence of double determinants of several local varieties of the same species which interbreed with one another. The polymorphism of bees and other animals which form communities, requires, however, the assumption of triple or quadruple determinants. In these animals the female half of the double determinant again becomes doubled, and this may also be the case as regards the male half (Termites).

Lastly, the assumption of double determinants in the idioplasm accounts for *temporary* dimorphism, such as seasonal dimorphism.

The occurrence of dimorphism is in all cases attributable to the presence of two kinds of determinants; but the causes which determine which of the two is to become active, are extremely varied, and cannot in many cases be accurately indicated. The determining influences, however, are always external ones — such as fertilisation, nutrition, and the effect of light in cases of *dichogeny* in plants.

It is self-evident from the theory of heredity here propounded, that only those characters are transmissible which have been controlled — *i.e.*, produced — by determinants of the germ, and that consequently only those variations are hereditary which result from the modification of several or many determinants in the germ-plasm, and not those which have arisen subsequently in consequence of some influence exerted upon the cells of the body. In other words, it follows from this theory that *somatogenic or acquired characters cannot be transmitted.*

This, however, does not imply that external influences are incapable of producing hereditary variations; on the contrary, they always give rise to such variations when they are capable of modifying the determinants of the germ-plasm. Climatic influences, for example, may very well produce permanent variations, by slowly causing gradually increasing alterations to occur in certain determinants in the course of generations. An apparent transmission of somatogenic modifications may even take place under certain circumstances, by the climatic influence affecting certain determinants of the germ-plasm at the same time, and when they are about to pass to that part of the body which they have to control. This is indicated by the climatic variations of the butterfly *Polyommatus phlœas*.

The primary causes of *variation* is always the effect of external influences. Were it possible for growth to take place under absolutely constant external influences, variation would not occur; but as this is impossible, all growth is connected with smaller or greater deviations from the inherited developmental tendency.

When these deviations only affect the soma, they give rise to temporary non-hereditary variations; but when they occur in the germ-plasm, they are transmitted to the next generation and cause corresponding *hereditary variations in the body*.

Since the germ-plasm undergoes a very considerable growth from the fertilised egg-cell to the germ-cells of the offspring, minute fluctuations continually take place in the composition of its vital units, the biophors and determinants. If permanent and constant influences, such as those of climate, act upon them, these minute fluctuations will become accumulated in the course of time and generations, and may thus give rise to appreciable individual variations, and then gradually to racial, and even perhaps to specific characters. If an influence acts in a certain direction for a short time only, it alone may or may not give rise to an individual variation in the soma, according to the number of ids of the germ-plasm affected by it. Whenever a *majority* of ids become modified, a corresponding variation must appear in the soma. As, however, an intermingling of the ids takes place twice, owing to the successive processes of 'reducing division' and amphimixis, minorities of modified ids may be increased to majorities; and sexual reproduction may then cause the fluctuating material for *invisible* variations in the determinants to give rise to *perceptible* somatic variations, and these are made use of by natural selection, aided by constantly recurring amphimixis. The latter process gives natural selection a choice of innumerable combinations of the most diversified variations, resulting from the constant minute fluctuations of all the units in the germ-plasm.

Strictly speaking, *the process of amphimixis alone* cannot bring about an *increase or decrease in the development of a character;* though it may, indeed, establish it more firmly in the germ-plasm by causing an increase in the number of ids, the determinants of which produce the character. An increased development, in the ordinary sense of the term, may, it is true, take place by the extension of a variation over *larger areas* of the body; the multiplicity of the ids, and the possibility of the constant production of new idic combinations by the process of amphimixis, accounts for the statement of breeders that the constancy of a character, as well as its increased development, may be affected by selection. The so-called 'individual potency' must, moreover, be due to the presence of a large number of homodynamous determinants for all the more important characters, and it probably results, not only from breeding a race true for a long time, — although this is of course necessary, — but also from favourable combinations of ids being produced by the processes of reducing division and amphimixis.

Variations do not, however, depend merely on modifications in the composition of a determinant or group of determinants, but frequently result from a doubling or further multiplication of the latter; and this must also depend primarily on modified external influences, such as those produced by changes in the nutrition of a part of the germ-plasm. The apparently sudden appearance of parts — such as feathers and other epidermic structures, as well as of certain pathological structures, such as the supernumerary fingers and toes of human beings — may be explained in this manner. All such variations do not, indeed, *actually* arise suddenly, but take place gradually in some of the ids, and only suddenly become apparent when they have accumulated to form a majority.

The *suddenness* with which variations appear is, in all probability, only apparent in most cases, as is well shown by Hoffmann's experiments on wild plants, in which variations were produced by abnormal conditions of life. The *degeneration* of parts which are no longer required, or have simply become useless, is due to the reduction and final disappearance of the corresponding determinants from the germ-plasm. But as this again depends on the fluctuating variations of these determinants in the different ids, it will not occur to the same extent in all the ids at the same time; and thus the remains of these reduced determinants are often preserved in individual ids through countless generations, and may occasionally cause reversion to take place when they have accumulated in consequence of the 'reducing division' and amphimixis.

Sudden variations of buds have only been observed in plants which also are, or have been, propagated sexually, and in which the structure of the germ-plasm is therefore just as complex as in species in which sexual reproduction *alone* occurs. These variations are also due to the effects of dissimilar modifying external influences on the determinants contained in the 'blastogenic' germ-plasm, which is passed on from cell to cell during the process of growth. It would, however, be impossible to understand why only a single bud out of millions should undergo transformation unless some other cause were also at work. This may be due to occasional irregular nuclear divisions, which would give rise to a similar result to that produced by amphimixis in reproduction by seeds, the modified determinants of individual ids occasionally becoming accumulated and then taking effect.

The power of transmission of '*sudden*' *variations in plants*, which is apparently very capricious, may be easily understood in principle. As the modification never occurs in *all* the ids of the germ-plasm, but only in *many* of them, and as this majority may be a slight or a considerable one, the transmission of the variation will depend on whether the majority is *often* obtained and even increased, or whether it becomes diminished, or even entirely lost, during the reducing divisions and amphimixis, when the plant is reproduced by seeds. In the case of the first alternative, the 'sport' will be transmitted; while in that of the second, transmission will only occur rarely or not at all. Even details of the apparently enigmatical phenomena of heredity of known 'sport' varieties — such as those of the balsamines, weeping ashes, the variegated variety of *Ballota nigra*, and others — thus receive a very simple explanation.

The capricious transmission of bud-variations by seeds, which only occurs in the smaller proportion of cases, cannot be explained so easily. It is due to the 'blastogenic' germ-plasm and the 'reserve germ-plasm' — destined to form germ-cells — following different courses, and consequently they will not always contain the same number of modified ids. The infrequency of the transmission of bud-variations by seeds may depend on the production of a new combination of ids of the 'reserve germ-plasm' from which the germ-cells are formed, whenever this formation occurs, *owing to the 'reducing division'* and amphimixis. No such occurrence takes place in the 'blastogenic' germ-plasm as long as merely asexual reproduction continues.

According to our view, the power of transmission — which is possessed by all organisms, and on which the development of the higher organic forms is based — therefore depends on simple growth merely in the case of the very lowest conceivable organisms with which we are not acquainted; while in all forms which have already undergone differentiation, it results from the possession of a *special apparatus for transmission*.

This apparatus first occurs in the unicellular organisms, in which it consists of a substance composed of the different kinds of vital units or biophors, which occur in the substance of the organism, and presumably in a similar proportion; there are, at any rate, numerous individual biophors of every kind, all of which are arranged together on a definite plan. This substance is surrounded by a membrane, — the nuclear membrane, — provided with pores, through which the biophors of the nucleus can pass into the cell-body, there to multiply at the expense of the nutritive materials — to which the vital particles of the cell-body themselves may become reduced under certain circumstances — and to become arranged in virtue of the forces dwelling within them.

To these processes is due the power possessed by the organism of giving rise by division to two complete individuals of a similar nature.

Even at this stage of differentiation, the hereditary substance is rendered more complicated by the process of amphimixis, or mingling of individual differences, in which this substance periodically becomes halved, and is then again completed by the hereditary substance of another individual. The result is, that every part of the organism is represented in the hereditary substance by different varieties of the same kind of biophor, and that, consequently, the individuals subsequently arising by division will be approximately intermediate in structure between the two parents.

In the multicellular forms exhibiting cell-differentiation, the apparatus for transmission becomes more complicated the more numerous and diversified are the kinds of cells composing the organism. Multiplication can only take place if each individual originates in, and again returns to, the unicellular condition. The division of the entire organism would only result in the production of two unequal halves, which could not of themselves undergo completion, and would require a special apparatus for the purpose. In order that this may arise, the previous *production of an apparatus for transmission*, adapted for reproduction by unicellular germs, is indispensable.

The production of this apparatus results from the formation of a *germ-plasm*, *i.e.*, a nuclear substance which contains reserve biophors for the construction of the corresponding cell-body, as well as for the formation of all the cell-bodies of the entire organism; and all of which are connected together into a definitely arranged structure, in such a manner that the constituent parts share regularly and successively, and not simultaneously, in the control of the cell-body. In order that this result may be produced, the smaller vital units or biophors are combined to form those of the next higher order — the determinants, — each of which controls *one* kind of cell, and consequently includes all the biophors required for the determination of this particular kind of cell. *The germ-cell contains at least as many determinants as there are different cells or groups of cells in the fully-formed organism which are capable of being individually determined from the germ onwards.*

Since the process of amphimixis or '*intermingling of individual differences*' is also retained in multicellular forms, the individual germ-cells must for this reason alone contain a mass of germ-plasm, each unit of which contains all the kinds of determinants of the species in close combination. The hereditary substance of the germ-cell thus came to be composed of ids and idants.

The multiplication of multicellular organisms by fission and gemmation results from a considerable increase in the complexity of the apparatus for transmission, in which process not only the determinants required for the control of their own nature, but also ids of germ-plasm in an *unalterable condition* — in which they are at the time incapable of undergoing disintegration — were distributed to certain cells of the body. This addition of latent germ-plasm to certain series of somatic cells also results in the formation of germ-cells in most multicellular forms; while the power of regeneration depends on a systematic addition of certain inactive determinants, or groups of determinants, to certain cells of the body.

Further complications of the germ-plasm produce the phenomena of alternation of generations and the polymorphism often connected with it, as well as the sexual dimorphism always occurring in a greater or a less degree in connection with 'sexual reproduction.' All determinants and groups of determinants which exist in two or more forms, must be present in a double or multiple condition in the germ-plasm, and be so arranged that each constituent part only becomes active in turn. This assumption is, however, insufficient in the case of alternation of generations, in which several kinds of germ-plasm must be present and become active in turn.

Thus an ever increasing complexity of the substance which renders the repetition of the organism possible is gradually produced in the phylogeny of living beings, and eventually reaches so high a degree that it is difficult to believe that such an infinite complexity of structure can actually exist in particles so minute. The more deeply, however, we penetrate into the phenomena of heredity, the more firmly are we convinced that something of the kind does exist, for it is impossible to explain the observed phenomena by means of much simpler assumptions. We are thus reminded afresh that we have to deal not only with the infinitely great, but also with the infinitely small; the idea of size is a purely relative one, and on either hand extends infinity.