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HEREDITY AND ITS VARIABILITY

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THE ESSENCE OF HEREDITY

In all textbooks and manuals on genetics heredity is usually taken to mean only the reproduction by living organisms of beings similar to themselves. Such a definition, in my opinion, contributes little to an understanding of the phenomenon of heredity. From time immemorial people have known that from wheat seeds you get wheat, from millet, millet. etc. This makes it possible for practical farming to propagate a particular species or variety of plant, or animal breed. No deeper conception of the phenomenon of heredity can be derived from the above definition.

Exponents of modern genetics (the science which studies the phenomena of heredity), who take as their premise the definition that heredity is only the reproduction of likes by organisms, have been studying heredity by ways and means which do not permit the investigator to find out anything about the essence of the heredity of any particular living body. What they study is not the phenomenon of heredity but the ultimate differences between organisms that differ in heredity.

The method employed in genetics to study heredity is to take two breeds, two organisms known to differ in heredity and to blend them by crossbreeding. There are those who want to find out things about the heredity of organisms they are investigating or the heredity of their characters from the diversity of the progeny obtained. All one can find out in this way is how many offspring resemble the one parent or the other. But one cannot determine, from the data furnished by such experiments, what the essence of the heredity of either parent consists in.

Our definition of the phenomenon of heredity differs from that which has hitherto been accepted in genetics. By heredity we mean *the property of a living body to require definite conditions for its life and development and to respond in a definite way to various conditions.* By heredity we mean the nature of the living body. We are therefore of the opinion that "the nature of the living body" and "the heredity of the living body" are about the same thing. For example, why do wheat plants differ from rice plants? Because these plants differ in their natures. Similarly it may be said that wheat differs from rice because wheat has a different heredity from that of rice. To study the heredity of an organism means to study its nature.

The nature of a living body differs in principle from the nature of a nonliving body. The more a nonliving body is isolated from the action of or interaction with environmental conditions, the longer it will remain what it is. A living body, on the other hand, absolutely requires definite environmental conditions in order to be alive. If a living body is isolated from the external conditions it requires, it ceases to be alive, ceases to be what it is. Precisely herein lies the difference in principle between a living and a nonliving body.

Different living bodies require different environmental conditions. We therefore know that they differ in nature, in heredity. Knowledge of the conditions required by a living body and of its responses to the operation of various conditions means knowledge of hereditary properties of that body. Consequently, *to ascertain the environmental conditions required by a living body (organism) for the development of particular characters or properties is tantamount to studying the nature, i.e., the heredity of these particular characters or properties.*

A study of the heredity (nature) of a given living body does not require the crossing of that plant or animal with one possessing another heredity. The real purpose of studying heredity is to determine the relation of an organism of a given nature to its environmental conditions. But after crossing, the offspring obtained do not possess the nature that it is desired to study. When studying heredity various crosses are needed only when one wants to determine the potency, or stability, of one heredity in comparison with another or others.

A knowledge of the natural requirements and relation of an organism to environmental conditions makes it possible to govern the life and development of this organism. More. Such knowledge may serve as the basis for changing the heredity of organisms in a definite direction.

To take heredity to mean—as has been done hitherto in genetics—only the reproduction of likes, without going into a study of the ways and the material (conditions) from which the body reproduces itself is tantamount to barring one's own way to mastering this important and interesting phenomenon of living nature.

It has been pointed out above that according to the line formerly followed in genetics, in order to study the heredity of a given character one must take a plant possessing this character and another plant absolutely different in nature, in heredity, from the given character. After crossing them the offspring of these two parents are examined to determine how many descendant plants have the character peculiar to the one parent and how many have the character observed in the other. Such a study, however, will not show in what the heredity of either of the parents taken for the investigation consists.

The difference between our approach to the study of heredity and the methods of the Mendelist-Morganist geneticists can be illustrated by the following example. The property of winter or spring habit is doubtlessly inheritable. In their repeated studies of the heredity of these properties the geneticists took plants of the winter variety and crossed them with plants of the spring variety. They then determined in the offspring how many winter plants, i.e., plants similar, as regards this character, to the one parent, were obtained, and how many spring plants, i.e., plants similar to the other parent. In some experiments they arrived at the conclusion that the hereditary properties of the winter habit differ from the hereditary properties of the spring habit in 1, 2, 3, etc., genes, granules of some unknown substance of the living body presumably contained in the chromosomes of cells of the winter or spring plants. However, what the essence itself, i.e., the nature of the winter or spring property of cereals, consists in, how to control the development of these properties, does not appear at all from the above study. But if the heredity of an organism or of separate properties or characters of it is characterized by the environmental conditions required for the development of these properties and characters, there is revealed to us the essential nature of the given properties or characters.

Thus, on studying the causes of the failure of winter cereals to ear when sown in spring we ascertained that one of the processes of development of winter plants now called the stage of vernalization requires, in addition to the food, moisture and air existing in the fields in spring, a relatively lengthy period of time of low temperature, 0-10°C. above zero. The absence of a lengthy period of low temperature in the fields in spring is the very reason why the process of vernalization fails to take place, and hence why all further development is retarded, why there is no earing and fruiting.

With the discovery of the nature of the vernalization stage it has become possible to compel any winter grain sown in spring to ear and bear fruit. For that purpose properly moistened seeds are kept in the field before sowing for a definite time under relatively low temperatures (vernalization). Thus the inherited requirements for transition (development) through the indicated process are satisfied. After its completion at the growing point of the young plant or in the embryo in the seed all further inherited requirements are satisfied by the existing field conditions when such seeds are sown in the field in spring and development continues normally until it is completed, i.e, until the plants ripen. This is the kind of study we engage in to determine the essence of the heredity of the winter habit.

Upon studying a considerable assortment it appeared that some varieties of bread grains possess greater winter habit, i.e., require a longer period of low temperatures, while others possess less winter habit, require a shorter period of low temperatures. Varieties that, according to their nature, can undergo the process of vernalization under the usual spring and summer conditions are called spring varieties in practical farming.

We, on studying heredity, ascertain the conditions of life, the conditions of development, required by the organism or by separate processes, and also the relation of the organism or separate processes of it to various environmental conditions. We thus arrive at a comprehension of the essence of heredity. The geneticists, on the other hand, do not study the essence of heredity. All they find out is how many offspring resemble the one parent with regard to a particular character and how many the other.

It is well known that a living body builds itself from the conditions of its environment, from its food in the broad sense of the word. It is likewise well known that the embryos of different breeds, for instance, of particular varieties of plants living in the same environment, build their bodies differently; hence different organisms are obtained.

Each organism develops, builds its body, according to its nature, its heredity. For example, you can feed a calf and a lamb the same hay. But while they assimilate the same hay, the lamb, following its nature, will develop and grow into a sheep and the calf into a cow. Everybody knows that not only do sheep and cows differ sharply as organisms but also that the quality and properties of mutton and beef differ in many respects, though both types of flesh are derived from the same fodder, in the case stated, from the same hay.

Such examples go to prove that every living body builds itself from the environmental conditions in its own fashion and in accordance with its own nature, its own heredity.

One can also readily notice—and people knew this long ago—that as a rule each generation of plants or animals develops in many respects like its ancestors, especially its nearest ones. This accounts for the definition accepted by genetics that heredity is the property of reproducing beings similar to oneself. *But reproduction of likes is a characteristic trait common to all living bodies.* Hence the mere statement of the above-mentioned common property of living bodies, a property long known to all, cannot characterize to any extent the concrete heredity of a given living body. A study of concrete heredity requires that one follow the course of development of the organism possessing the given heredity, and determine the conditions necessary for its development as well as the reaction of the organism to the influence of its environment.

It is not only the organism as a whole that can reproduce bodies similar to itself. Every cell of the organism, every granule of a living body can reproduce its likes. For example, a cell of a young stem will reproduce stem cells, a cell of a leaf will reproduce leaf cells, a cell of a rootlet will reproduce rootlet cells. Every organism grows by its various cells reproducing cells similar to themselves.

THE ESSENCE OF VARIABILITY. GROWTH AND DEVELOPMENT

While it is known that an organism and also its individual cells and the various particles of them reproduce bodies similar to themselves, one must not forget another aspect of this property of the living body, namely, that the organism as a whole as well as the separate parts of its body reproduce, in some measure or other, bodies dissimilar to themselves. For instance, an egg or a zygote, after a definite interval of time and under suitable conditions, reproduces many thousands and even millions of cells wholly dissimilar to the first, original cell, i.e., the zygote from which they sprang. The case of a bit of begonia leaf developing into a full-grown plant may also be instanced. Here begonia leaf cells reproduce root and stem cells, i.e., cells unlike those from which they originate.

Consequently, although it is characteristic of the nature of a living body to reproduce bodies similar to itself, yet simultaneously cells and individual differences that enter into the contents of cells are capable, in various measure or degree, of reproducing also bodies dissimilar to themselves.

The ability of the separate cells of an organism to reproduce not only likes but also unlikes has never been questioned in science. What has been disputed, and for centuries at that, was the fact that an organism as such can reproduce organisms not only similar to itself but also differing from itself. The point involved is the variability or invariability of the nature of living beings.

When Darwinism made its appearance short shrift was given to the unchangeability of living nature. Today no scientist of reputation anywhere on earth will assert that living nature has not changed. The variability of living nature and the possibility that it may change are admitted. But up to now the causes of changes in the nature of organisms and the concrete ways in which these changes take place are not sufficiently known to science to make it possible to alter the heredity of an organism at will in any definite direction. Therefore modern genetics, while abstractly recognizing that living nature is variable, in practice conducts its investigations, makes its deductions and draws its conclusions from them on the assumption that the heredity of an organism cannot be changed by the conditions of its life. Such a science therefore maintains that it is impossible for the conditions of life to influence the variability of the nature of plants and animals in a desired direction.

Our Soviet science, the Michurin trend in science, gives a clear understanding of the way to change the nature of an organism.

Our conception of the phenomena of heredity, the changes in these phenomena and the regulation of heredity is based on the following premise:

Every living body builds itself out of nonliving material, in other words, out of food, out of the environmental conditions. The organism picks from the environment the conditions it needs; but this choosing of conditions is dependent upon the heredity of the given organism. Whenever an organism finds in its environment the conditions which it needs and which are suitable to its nature, its development proceeds in the same way as it proceeded in previous generations of the same breed (of the same heredity). When, however, organisms do not find the conditions they require and are forced to assimilate environmental conditions which, in one degree or another, do not accord with their nature, organisms or parts of their bodies result which are more or less different from the preceding generation.

If the altered part of the body is the starting point for a new generation, the latter will differ from the preceding generations in its requirements and nature. From the biological point of view we can find out the difference between these generations. It will consist of a difference in the requirement of environmental conditions. The particular conditions were unsuitable for the preceding generation and the body assimilated them of necessity, perforce, as it were. But if it imbibed them, assimilated them, a body with new properties, with a new nature, was obtained. These conditions will now be requisite for it. Thus *the cause of change in the nature of a living body is* *a change in the type of assimilation, in the type of metabolism.*

Being included in, assimilated by, the living body the external conditions cease to be external and become internal conditions, i.e., they become particles of the living body, and their growth and development now require the food, the environmental conditions that they were themselves in the past. The living body is composed, in a way, of separate environmental elements which have become converted into elements of the living body. The growth of the separate parts and granules of the living body requires the same environmental conditions by means of the assimilation of which the organism originally built these parts and granules of its body. Thus, by regulating the conditions of life, new environmental conditions may be included in, or this or that element expelled from, a living body.

Whether separate elements are included or have been excluded from a living body may be judged by the environmental conditions it requires for its growth and development. For instance, the process of vernalization of spring cereals does not require low thermal conditions. The vernalization of spring grains proceeds easily at the usual spring and summer temperatures in the fields. If spring cereals are vernalized for a long period under low thermal conditions one may not infrequently observe that one or two generations later the spring habit of the wheat will change to winter habit. And, as everyone knows, winter grains cannot undergo vernalization without low temperatures. We show by this example in what way new external conditions were included in the nature of the living body, and that thereby the progeny of the given plants acquired a new requirement, the requirement of low thermal conditions for vernalization.

Changes in requirements, i.e., in the heredity of a living body, are always adequate to the action of the environmental conditions, if these conditions have been assimilated by the living body.

As was remarked above, the different elements of an organism, its organs, cells and separate parts in cells, possess the property of reproducing themselves. For example, we know that if in leaf cells the plastids from which chlorophyll grains develop disintegrate for some reason or other, then all cells which come from the cells that lost their plastids will be albinos, i.e., white, not green. In the case stated the chlorophyll grains will not reproduce themselves, there will be nothing to do the reproducing.

Each molecule and atom of a living body, if one may put it that way, reproduces itself at certain moments. *But all these different molecules and cells in the organism are obtained from* *zygotes by reproduction of bodies that are not similar but dissimilar to themselves, by differentiation, i.e., development.*

From the initial cell (the zygote) we obtain a group of cells which are unlike the cell we started with. There are no plastids (and other things besides plastids) in the initial cell (the zygote) of the plant; they appear in the cells obtained from the zygote. In cell multiplication the plastids and all other separate parts reproduce themselves, so to say. Consequently, the *reproduction of likes is only one of the properties of the living body. Another of its properties is the reproduction of unlikes.*

The direct reproduction of likes by each cell and each molecule of the living body we call growth of the body. For instance, leaf cells reproduce likes, and as a result the leaf gets bigger, or grows, as they say. By the growth of a body we mean increment of weight and volume.

The reproduction of like by like may, however, come about not only by means of growth but also by means of development.

The reproduction of likes, not directly but through a long chain of conversions of unlikes, until beings similar to the initial one are obtained we call development. There is a qualitative distinction between these two means of reproducing likes.

To exemplify the first means of reproducing likes let us point out the following. The cell of a leaf grows and develops, then divides in two; instead of the one we have two but both remain leaf cells. The leaf increases in size, i.e., grows. This process is what we call growth. Another example might be given, that of a leaf and, of course, of its cells also reproducing bodies similar to themselves, but in a different way—through a chain of conversions. By means of grafting Comrade A. A. Avakian substituted for the ordinary, dissected leaves of tomatoes of the Albino variety leaves of another tomato variety which resembled potato leaves, i.e., pinnate in shape. Seeds were taken from a fruit that had developed on a twig of the Albino variety. This variety, as has been stated, has dissected leaves, in accordance with its nature. After these seeds were sown in the summer of 1941 at the experimental base of the Lenin Academy of Agricultural Sciences of the U.S.S.R. at Gorki Leninskiye, quite a few plants were obtained whose leaves were not dissected, but like those of the potato plant. The question may be asked why, despite the fact that it is in the nature of the Albino variety to have dissected leaves, some of its offspring happened to have nondissected leaves, leaves resembling those of the potato plant. The reason is that the plant from which the seeds were taken had leaves like those of the potato plant which had been substituted for the dissected ones by means of grafting. It was they that had reproduced themselves in the progeny.

Substances elaborated in the leaves united with substances of the neighbouring cells, were modified, were converted, developed. From these cells altered substances united with substances of other cells and altered still more. In this manner the conversion went further and further away from the leaf cells until it became a component element of the embryo. In this way, we believe, *the hereditary basis of each organ, of each character, of each property of the organism reproduces itself for generations.*

INDIVIDUAL DEVELOPMENT OF THE ORGANISM

The development of an organism, like its growth, proceeds by means of conversion, of metabolism. The sex cells, buds or eyes from which usually entire organisms develop are, as a rule, the product of the development of the whole organism which gave rise to the particular initial bases for the new organisms. They arise and build themselves out of molecules, granules of substances—transformed many times (but in accordance with natural law)—of various organs and body parts of the organism. Therefore all the former properties of the plant that produced the sex cells or, for example, the eyes of potato tubers are accumulated, as it were, in these cells or eyes. Hence the initial cells also express to a greater or smaller extent the tendency of the future properties of the organism.

In development from a fertilized sex cell, i.e., from a zygote, the changes and conversions are, as it were, a repetition of the path traversed by the ancestors, particularly the nearest ones. The process which in the preceding organism went on at the very beginning will be the initial process also in the new generation; the process following the first one will be the next also in the offspring, etc. Figuratively speaking, the development of an organism may be depicted as the unwinding internally of a spiral that was wound up in the preceding generation. This unscrewing is at the same time a screwing up for the future generation. After all, the formation of a given organism proceeds on the basis of the development of the preceding one. And in the process of development of that particular organism the basis of the future generation is formed. I consider it correct to say: *to the extent that the body of a particular organism (say, of a plant), is built de novo in the new generation to that same extent, naturally, all its* *properties, including its heredity, are obtained de novo, i.e., to that same extent also the nature of the organism is obtained de novo in the new generation.*

Each organ and each character reproduces itself in the course of generations both by means of growth and by means of development. The sex cells and any other cells by which organisms are reproduced are, as a rule, created, obtained as a result of the development of the entire organism, by means of conversion, by means of the metabolism of the various organs. As a result the course of development gone through is accumulated, as it were, in the cells from which the new generation takes its start.

The primary initial cells, from which the organism develops, are the biologically most complex and possess the greatest possibilities of development. All other cells resulting from the development of the zygote when the tissues are being differentiated are biologically less complex and possess fewer potentialities of development. For instance, a whole organism may develop, be obtained, from a sex cell or a bud (eye) of a potato tuber. But from the leaf cells of many plants it is impossible to obtain whole plant organisms.

The assertion of the Mendelist-Morganist geneticists that all cells of an organism possess one and the same nature, one and the same heredity, will not hold water. Different cells of the same organism undoubtedly possess different natures, different heredities, different potentialities of development. All you need do is take from a potato tuber as initial eyes not the usual ones but such as developed from tuber cells from which they normally do not develop, and you can observe not infrequently that plants of a different nature, of a different variety, are obtained. We know of quite a number of cases when new organisms, different in their nature, may be obtained from cells of one and the same plant organism. It has already been pointed out that by far not all cells of even plant organisms can give rise to or regenerate entire organisms. This also goes to show that not all cells of an organism are of like nature. Different cells of an organism possess different natures, i.e., different heredities.

The development of an organism from a zygote is, as it were, the differentiation, the disintegration of a biologically more complex cell into simpler, more differentiated cells. The egg is biologically more complex than any cell of the organism that originated from it.

It must not be forgotten that cells differing in quality can be and always are obtained from one and the same quality of initial material, for instance, from one cell or a group of like cells, in the process of development, in the process of metabolism. These different qualities of cells are determined by the environmental conditions. *The environmental conditions are the differentiating material of the developing organism. These conditions are assimilated by the living body and thus the body changes itself, differentiates itself.*

For instance, the shoots of plants which spring up from the soil have white leaves. The cells of these leaves already contain plastids but the latter may turn into chlorophyll grains, in consequence of which the leaves become green only when subjected to the influence of light. In the case at hand light, together, of course, with the other environmental conditions, is the differentiating material of the plastids; as a result the plastids are transformed into chlorophyll grains.

The presence in plants of particular characters or properties is usually due to the fact that the latter existed in the parent organisms and, by means of conversion, of development (metabolism) were incorporated and accumulated in the sex cells, in the initial cells of the new generation. But numerous cases could be cited in which a particular character of the organism in question did not exist in the parental forms. It had been present in the older preceding generations and appeared anew only after several generations. This particular character or property had been, as they say, in a latent or recessive state. To explain this fact let us return to the example of the character of green colour in wheat leaves. When the young leaves appeared on the ground they had no green colour. There was no chlorophyll in them. But they had the substances, plastids, which are converted in these leaflets, in the light, at a proper temperature, into chlorophyll grains. You can grow part of the plant, a separate stem of it, in the dark, shut out the light from the leaves, and they will always be etiolated, yellow. In the given case no green colour will form. But if seeds are obtained on such a stem and plants grown from these seeds in the light, the leaves will be green-coloured, the chlorophyll grains will develop. In the preceding generation the green-colour character, the chlorophyll, had been missing but in the succeeding generation it appeared. There is no difficulty in understanding the cause of its appearance. The internal matter, in the present instance the plastids, which is transformed into chlorophyll grains existed in the leaves of the preceding generation. These plastids reproduced themselves, entered into metabolic relations with other substances of the living body and in the final analysis participated in the creation and development of the sex cells, the germs of the future generation. But the plants of the succeeding generations continued the normal development of the plastids into chlorophyll grains when their leaves were exposed to the action of light. The plastids possessed this property also in the preceding generation but did not develop chlorophyll grains because the necessary conditions, i.e., light, were absent. By such reasoning one can readily understand the cases where particular characters or properties of organisms do not develop for many generations and then suddenly appear and develop. The latent internal possibilities find the conditions they need for development, find a suitable environment, which explains the appearance of this or that character or property not possessed by the previous generation.

All properties and characters of an adult organism may, in a certain sense, be called latent, recessive, i.e., not manifest while the organism exists in the form of an embryo or germ. In the zygote all the characters and properties of the organism exist in latent form, as it were.

It has already been said above that a living body reproduces itself, that the different cells, granules and molecules of the body possess different natures—different heredities, different properties.

The molecules of the protoplasm and the molecules of the chromosome likewise possess, if one may put it so, different heredities, different natures. But all these living granules reproduce themselves both by means of growth and by means of development.

Proceeding from these premises we assume, and in particular instances can prove experimentally, that if you take separate groups of cells, separate parts of an organism as the fundamental, initial element you obtain a new generation having different properties and different characters, i.e., a different heredity from the one there was, or, generally speaking, from the old initial breed or variety. This can be observed, for example, in potatoes when they grow adventitious buds, i.e., eyes from the tuber pulp. After rearing plants from such eyes a new breed, i.e., a variety with different properties, is frequently obtained.

Such facts go to show that different cells of the same organism may possess different natures, different heredities. It goes without saying that organisms cannot be grown from all cells. Many cells do not possess the property of restoring the whole organism.

The same line of reasoning may be applied to difference in quality in the sense of the heredity of separate parts and separate granules of a cell. Changes in separate parts of a cell, such as, for instance, separate chromosomes, should (and this is frequently proved experimentally) bring about a change in the various organs, characters and properties of the organism obtained from this cell with altered chromosomes or sections of chromosomes, or with changed granules of protoplasm in the initial cell.

A change in this or that section or granule of the initial cell in various degrees affects the changing of the various characters and properties of the organism obtained from this cell.

Not all granules of the original cell or group of cells are to the same extent starting points for the development of the various characters and properties of the organism. At the same time it is necessary to know that individual granules of the original initial cell cannot turn, cannot develop into organisms. This requires a totality, a complex of all granules, i.e., a whole initial cell or, as for instance in vegetative multiplication, a group of cells.

ORGANISM AND ENVIRONMENT

The relative purposiveness and adaptability of the plant and animal world to external conditions and to their surroundings, as well as the harmony, the adjustment of the various organs of the organism to the discharge of particular functions, are excellently explained by Darwin's theory of natural and artificial selection. Changes beneficial to development and survival under given conditions make for the numerical increase, the propagation of such individuals, while changes deleterious to survival make for a decrease in the number of such organisms. This explains the progress, the constant process of perfection in the nature of plant and animal forms. In practical farming, plant varieties and animal breeds are improved by means of artificial selection.

Three interconnected factors enter into our conception of natural and artificial selection: heredity, variation and survival. The diversity of plant and animal forms both in nature and in practical farming was created and is still created by natural and artificial selection. But the source, the material out of which organisms create or build themselves, is the environmental conditions—food in the broad sense of the word. Different living bodies elect different conditions from the environment, in accordance with their natures, assimilate them and biuld their bodies in conformity with the laws of their individual development, i.e., in accordance with their heredity.

Different species and genera of plants and animals require different environmental conditions for their life and development. Likewise, the same organisms require different environmental conditions in different periods of their lives. For instance, winter plants require low thermal conditions for one of their periods, now called the phase of vernalization. During the other periods of their life winter plants do not require low thermal conditions. Finally, the same plant organism requires different environmental conditions at one and the same time, but for the life and development of different organs and for undergoing different processes. Thus, for instance, the conditions required for the development of the leaves and roots of a plant differ. In general, the development of the different cells, different parts of cells and separate processes of an organism requires different conditions of the external environment. Besides, these conditions are differently assimilated.

It must be stressed *that by external we mean all that is assimilated and by internal that which assimilates*. The life of an organism is complicated and proceeds through innumerable regular processes or conversions. As a result, food imbibed or entering an organism from the external environment is assimilated by the living body through a chain of various conversions, and from being external becomes internal. This internal matter, being living matter and entering into metabolical relations with substances from other cells and particles of the body, feeds them, as it were, and thus as regards them becomes external. Organisms, beginning with zygotes (fertilized sex cells) develop by means of manifold regular changes and transformations of the body, and they become adult, capable of forming the same kind of sex cells as those from which they themselves originated. This is what constitutes the course of the individual development of plant organisms.

If a plant organism does not find in its environment the particular conditions required by the nature, i.e., the heredity of a particular process or character, the process or character in question does not develop. In these cases the internal potentialities, i.e., the heredity, for the development of the given character exist. But the character fails to develop on account of the lack of the necessary environmental conditions, i.e., of the material necessary to enable the character to build itself. In cases where the failure of a particular process or character to develop does not disturb the general life and further development of the organism, the latter may continue to live and develop normally without developing the character or property in question. However, the undeveloped characters or properties of such organisms will, as they say, be latent or recessive. These characters or properties may develop in the succeeding generations if the environment contains the requisite conditions. For instance, winter wheat plants of the Ukrainka variety on ripening produce in some years spikes with black awns and in other years with white awns. Seeds obtained from black-awned and white-awned ears of the named variety, sowing conditions being equal, produce plants with awns of the same colour. The awns are white or black depending upon the year, i.e., upon the conditions under which they are grown. This indicates that in cases where ripe plants of the Ukrainka variety with white awns are obtained, the external environment did not contain the conditions without which black pigments cannot develop. But the internal conditions, the heredity, the potentiality, the requirement for the realization of this character exist. The awn cells contain the substance which on further development might have developed into black pigment, but owing to the absence of certain external conditions this substance did not develop further and the awns remained white. Thus in the case in question the white-awned plants possess those elements of the body which were not converted into black pigment only because their development ceased. But these elements, like all other granules and particles of the living body, may reproduce themselves in their progeny by means of metabolism, as a result of which they are incorporated, accumulated, in the sex cells.

The category in question also relates to cases of reversion, i e., the appearance in a particular generation of characters and properties which were lacking in its immediate parents but which existed in its earlier ancestors. There are many such examples and they are generally known.

In the same way we explain the so-called fluctuating variations of plant organisms of the same nature, i.e., the same heredity. Many of the properties or characters possible in a particular variety of plant remain recessive in each concrete case, i.e., do not develop without causing substantial damage to the organism as a whole. Hence, under various environmental conditions one may observe a diversity of plants (phenotypes) belonging to an identical variety, i.e., with the same heredity. The internal hereditary potentialities of development of particular characters are not realized and the characters do not develop for lack of the various environmental conditions. As a result different plants are obtained but of relatively the same nature, i.e., heredity.

No organism ever wholly realizes all its hereditary potentialities. Many properties and characters do not develop fully, remain to some extent undeveloped, recessive, without substantially affecting the development of the organism as a whole. But a plant has characters and properties, the lack of development or even underdevelopment and incompleteness of which hamper all further development and in some cases even prevent the organism from continuing to live. Such properties and characters of the organism clearly cannot be recessive, i.e., latent, since the whole organism wil cease to develop if they do not develop. For instance, if you sow winter-grain seeds in spring they will produce shoots and will for a long time be in a state of tillering, and roots and leaves will develop. But such plants are unable to initiate the formation of spikes and straws or reproductive organs. In winter plants sown in spring the process called vernalization cannot take place for lack of low thermal conditions. But spikes and straws cannot develop in cereals unless the plants have undergone the process of vernalization, i.e., without a corresponding qualitative change in the content of the cells in the cone of growth, although the environmental conditions for the development of these organs exist during both the spring and summer periods. In these cases the vernalization process, which does not develop but remains recessive, as it were, is the internal cause of the failure of the plants to develop further, of their failure to advance toward the formation of new seeds. Clearly no offspring can be obtained from wheat plants which formed no seeds. In the case in question the lack of seeds was caused by the failure to go through the process of vernalization. These are the premises from which we proceed when we say that processes, characters and organs which play a substantial part in the zation of individual development, but a development deviating from the normal, usual course. A change in heredity is usually a result of the development of the organism *under environmental conditions which in some measure or other do not suit* its natural requirements, i.e., its heredity.

The individual development of an organism, as has already been said, is a chain of regular transformations. If these transformations of the living body do not transcend the norm, i.e., if they are the same as they were in the preceding generation when the particular character or process was developing, there will be no change in heredity. In the generation in question the heredity is the same as in the preceding generation. However, in the development of the individual, deviations of the transformations from the norm, i.e., from the quality of analogous transformations occurring in the preceding generations, cause change in breed, in heredity.

The more the environmental conditions suit the requirements, i.e., the heredity of the organism, the more will the development of the given organism resemble that of the preceding generations and, consequently, the less will its heredity change, deviate from type, from the norm. When the organism does not find in its environment the conditions necessary for the development of particular organs or characters, these organs or characters may fail to develop altogether if they can remain recessive without detriment to the general development of the organism. If, however, the organism as a whole cannot continue to live and develop without their development, it either ceases to develop or the usual course of the process, the usual development of the organs and characters, must change and take a direction which corresponds to the new, unusual conditions. Thus *changes in the conditions of life which necessitate changes in the development of plant organisms are the cause of change in heredity.* All organisms which cannot change in accordance with the changed conditions of life do not survive and leave no progeny.

Organisms, and hence also their natures, are created only in the process of development. A living body may change also without development but these changes will not be characteristic of living bodies. Changes occurring in living bodies without a development of these bodies will, as a rule, involve a diminution of their vitality. For instance, seeds—the embryos of organisms of different plants—when stored do not develop like organisms, but when stored too long or stored under conditions that are not normal, changes take place in the cells of the embryos. Therefore the heredity of such seeds may also change. But such changes, as a rule, will lead to a decrease in vitality. The seeds may, due to long storage, be ruined, become less germinative, less vital.

In the development of plant organisms the heredity usually least subject to change is that of recessive characters, the undeveloped or underdeveloped state of which does not cause substantial harm to the general development of the organism. On the other hand, the heredity of those characters and properties of an organism whose development plays a substantial part in the life of the individual is in our opinion more frequently subject to change. If the external conditions do not correspond to the normal course of development of these characters or properties, either the course of their development must undergo adaptive change or the organism as a whole will cease to develop, to live.

In each new generation plants strive to manifest properties and characters which existed in the preceding generations. Some of the characters and properties which existed in a preceding generation may in the particular plant in question, owing to the lack of suitable external conditions, remain and as a rule always do remain in underdeveloped form; as they say, the character remained in a latent, recessive form. And, conversely, some of the characters and properties which did not manifest themselves in preceding generations may do so in the given generation.

In other words, where the heredity is relatively the same, the external appearance of plants of different generations or of different plants of the same generation may (and always does) differ more or less.

The diversity of plants with relatively the same heredity (i.e., of one variety) is due to the various degrees of development of many of its properties and characters one of which taken separately does not play an essential part in the general course of development of the organism as a whole. The heredity of such characters and organs, which easily vary in the development of the individual, is usually least conservative and lends itself most to change. Of this one can easily convince oneself by raising new plants from cuttings of tissue taken from such variable organs.

It is different with organs, characters and properties whose development plays an essential part in the life of the organism. Everything in the organism is directed towards providing the development of such organs or characters with conditions which do not transcend the norm. Therefore the development of such characters varies considerably less. Their heredity is usually more conservative and lends itself less to change, as it is guarded and protected to a great extent by the entire system of the organism as a whole.

Variation in the heredity of plant varieties propagated by seeds takes place, as a rule, through a change in the heredity of conservative characters, which vary with difficulty. It depends to a considerably smaller extent on the variation of the easily variable characters and properties of the plants.

Yet it has been repeatedly stated that a change in the body is always linked up with a change in its heredity. We seem to have arrived at a contradiction. A variety changes to a greater extent in those characters which are more conservative, less capable of change in the development of the individual, and on the contrary, a variety changes to a considerably smaller extent in those characters which in the development of the individual are less conservative and lend themselves more to change (variation). On this ground geneticists arrived at a wrong theoretical conclusion. They properly attribute the fluctuating variation of the characters and properties of plants and animals to the varying conditions of the environment. But inasmuch as the alteration of a variety goes on, as a rule, in the characters and properties which vary to a considerably smaller extent in the development of the individual, they conclude that a change in variety, and hence a change in breed, i.e., heredity, does not depend on the conditions of life at all but on certain unknown causes. In their opinion the causes of mutations have not been discovered to this day. An organism's characters and properties vary on account of the variation in the conditions of life, but its heredity, its breed, does not change. Consequently, the living conditions are not the cause of changes in varieties.

As a matter of fact the heredity of a living body changes normally only when this body develops. Whatever does not develop in the living body does not change in the sense of developing. It can change only in the sense of being destroyed or fading out of existence.

If the external environment does not contain the conditions required for the development of the various characters and properties which do not play a substantial part in the life of the organism, these characters and properties do not develop and consequently do not change. Recessive characters are, as a rule, the most stable, i.e., the least changeable. This or that character may not manifest itself for many generations in the plants of a given variety, may be latent for lack of the necessary environmental conditions. When the necessary conditions exist, recessive characters and properties can develop and assume the same form as in generations of the distant past. The heredity of such characters does not change for the reason that the latter did not develop. On the other hand, fluctuating variations in the individual development of many properties and characters of the progeny do not alter the characters or alter them but slightly for the following reason. As their properties are beyond the norm, the substances of the changed (variable) characters are not included in the processes, passage through which results in the appearance of organs or parts of plants which form the basis of future generations, as for instance seeds. Thus a variety propagated by seed usually changes little on account of a change in the variable characters, as they are called. This is so not because changes in characters are not determined by the action of environmental conditions, of conditions of life, but because the changed nature of the particular body parts of the organism is not included, or is included to a small extent only, in the chain of processes which leads to the formation of seeds. But if the changed characters or organs are taken as the starting point, as the basis for future organisms, the progeny too will be changed, i.e., the variety will be altered.

If the environment does not contain the conditions suitable for the development of the characters and properties without which the further existence of the organism is impossible, such characters and properties cannot easily remain recessive. They develop perforce, as they say, else the organism must cease to exist. Although the action (especially the prolonged action) of unusual, unaccustomed conditions of environment does bring about the development of the particular characters or properties they will, nevertheless, develop differently from the way they developed in the preceding generations, when environmental conditions were normal. As a result, a more or less different living body is obtained possessing in consequence different properties and, of course, a different heredity, i.e., different environmental requirements.

Changes in the nature of organisms and in their various properties and characters are always in some measure enforced. For lack of necessary conditions suitable to the nature of the given living body it is compelled to assimilate conditions differing to some extent or other from those required. As a result a different body, and hence also a different nature, or heredity, of that body, are obtained. If one adopts this point of view one readily arrives at the conclusion that the heredity of the different sections of a plant from which a whole organism can be regenerated is frequently different. This can easily be corroborated experimentally in many cases. We have already pointed to the experiment of obtaining various breeds of potato tubers from one initial tuber by inducing eyes in the particular tuber from various sections of its pulp. Reference may also be made to such well-known facts as the appearance on fruit trees of separate buds or twigs, with hereditary properties and characters differing sharply from those which are characteristic of the tree as a whole. The changed characters which play an essential part in the development of an organism as a whole are usually transmitted more frequently to the seed progeny than characters of less importance. This is so for various reasons, one of which, in plants, is the multitude of characters of the same type. The more characters of one type (for instance, leaves) there are, the less a change that exceeds the norm for each character is transmitted in the progeny.

DIRECTED CHANGE IN THE BREED OF ORGANISMS

There arises the question: why then do we have relatively permanent breeds of animals and varieties of plants, i.e., heredity, in animate nature and practical farming? Everybody knows of cases where animal breeds and plant varieties, as well as species and strains, have been preserved for decades on farms and for centuries in the state of nature. In such a space of time scores and hundreds of generations succeed each other, but as concerns their nature, i.e., their heredity, they are indistinguishable or almost indistinguishable from each other. This generally observed phenomenon likewise seems to contradict the view we have expressed above that the nature, i.e., the heredity, of an organism is compelled to change when the body of the organism changes under the influence of the conditions of life. After all, many characters and organs in each generation develop differently whenever they encounter conditions which are relatively different from those obtaining in previous generations. Relatively different characters, organs and properties with consequently different heredities are obtained. Logically it would seem that these organs and characters ought to reproduce their exact copies in the following generation. In actual fact, however, the innumerable experiments made have not confirmed this. Experiments of this kind are rather easy; anybody can repeat them. For instance, take seeds of some particular variety of, say, wheat and grow plants from them: some under good and others under bad conditions of nutrition and care. The plants obtained will differ sharply in external appearance. The plants grown under good conditions may be dozens of times the weight and size of those grown under bad conditions. The difference will be not only quantitative but also qualitative. It would seem that the heredity of such different living bodies (plants) should be different. But if seeds from these different plants are sown under equal conditions the plants that grow from them will, as a rule, differ little from each other.

Hence one may arrive at the conclusion that change in the living body apparently does not entail change in its heredity, i.e., its nature, and that consequently it is useless to look in the conditions of life of plants and animals for ways of directing change in the nature of organisms. This is precisely the erroneous conclusion arrived at by representatives of the science of genetics. Due to this cardinal error science (genetics) found itself at loggerheads with practical farming, with seed growing and pedigree stockbreeding.

I emphasize the fact that a rather large number of experiments were performed which seemed to prove beyond dispute that heredity is constant while the quality of the body is relatively variable. Moreover, they can easily be repeated if so desired. Let us refer to an experiment performed at the Belaya Tserkov Sugar-Beet Breeding Station. On a field sown throughout to one variety of sugar beet, 10,000 of the biggest roots were picked in autumn. Their average weight was 750 gr. On the same field were also picked 10,000 of the smallest roots, whose average weight was 150 gr. The two groups of roots, the biggest and the smallest, were planted apart from each other to avoid cross-pollination, a blending of the heredities of these two groups of plants possessing different weights. The seeds obtained from them were sown under identical conditions. It appeared that the average weight of the roots obtained from the big-root group was 317 gr. and of those from the small-root group 312 gr. The average weight of the roots was thus almost the same regardless of whether the seeds were taken from the biggest or the smallest sugar-beet roots. The logical conclusion may be drawn (and is drawn again and again by geneticists) that the conditions of life, of agrotechnique, undoubtedly affect crop yields, i.e., the development of the quantity and quality of the living body, but they do not exert any influence upon the quality of its nature, do not affect any alteration in its heredity.

This explains why some geneticists came to the conclusion that in sowing plants for seed as well as in breeding pedigree livestock the application of good agrotechnique or zootechnique, i.e., good feeding of pedigree animals and good tending of them, is not only unnecessary but frequently even wasteful. Such scientists are of the opinion that good farming technique or good feeding will only increase the number of seeds or the quantity of livestock products obtained, but that the quality of the heredity of the seeds or of the young stock will remain the same as with bad or cheaper agrotechnique or zootechnique. Yet it is a known fact that in *practical life good varieties of plants and good breeds of cattle always have been and are being produced only with good agrotechnique and zootechnique. When agrotechnique is bad you not only can never obtain good varieties from bad ones but in many cases good cultivated varieties become bad after a few generations.* The principal rule of practical seed growing is that plants grown for seed must be reared in the best possible way. This requires that good conditions suitable for the heredity requirements of the plants in question be established by means of agrotechnique. Of well-cultivated plants the very best are selected for seed. This is the way in which plant varieties are improved in practice. If the plants are cultivated badly (i.e., when the agrotechnique is bad) no selection of the best plants for seed will produce the results required. All seeds produced in this fashion are bad, and even the best among the bad will be bad.

It must be firmly borne in mind that while good agrotechnique, the creation of good conditions for the growing of plants, does not always improve their nature, i.e., their heredity, it never makes it worse.

If a detailed analysis of the question of change in heredity under the influence of the conditions of life of plants and animals is made it appears that there is no contradiction between the factual experimental material of the geneticists, on the one hand, and the supposedly opposite facts of practical farming, on the other. The facts set forth seem contradictory only to those geneticists who do not know life, who do not know farming practice. Therefore the conclusions which the geneticists draw from their above-mentioned experiments radically contradict good seed growing and pedigree-stock breeding practice. They further contradict the Darwinian theory of development of plant and animal forms.

The facts show that changes in the various sections of the body of a plant or animal organism do not become fixed, are not assimilated, with equal frequency in the sex cells, i.e., in the reproductive products. The geneticists claim instead that no changes in the properties, characters or organs which arise from the conditions of life induce changes in the heredity of these properties, characters or organs. The fact that the progeny obtained in their experiments with plants and animals under various conditions remain unchanged with regard to these properties serves the geneticists as the grounds on which to base their assertion. Actually a living body that has been qualitatively changed by the conditions of life always has a changed heredity. But not always by far can qualitatively changed parts of the body of an organism enter into normal metabolic relations with a number of other parts of the body, owing to which these changes cannot always be fixed in the sex cells. The offspring will therefore frequently not possess the changed heredity of a particular changed part of the body of the parent organism or this change will be expressed in weakened form or to a minor degree.

This is explained by the fact that the process of development of each organ, of each granule of a living body, requires relatively definite environmental conditions. These conditions are elected by each process, by the development of each organ and property from the surrounding environment. Hence if a particular part of the body of a plant organism is forced to assimilate conditions to which it is not accustomed (qualitatively or quantitatively) and if owing to this the given part of the body becomes changed, different from analogous body parts of the preceding generation, then substances passing from this part of the body to the neighbouring cells may not be elected by them, may not be included in the further chain of corresponding processes. Of course, there will be some connection between the changed part of the body of the plant organism and the other parts of the body, otherwise it could not exist; but this union may be incomplete or not mutual. The changed part of the body will receive some nourishment or other from the neighbouring parts; but it will not give up its specific substances as the neighbouring parts will not elect them. In their nature these substances are not native to the processes going on in these parts of the body. Into these processes will enter the conditions, the food suitable to them; and they can obtain this food from other, qualitatively unchanged parts of the body.

This explains the frequently observed phenomenon that certain changed organs, characters or properties of an organism fail to manifest themselves in the heredity of the progeny. At the same time we stress the point that these altered parts of the body of the parent organism possessed an altered heredity. These facts have long been known to practical horticulture and floriculture. A changed twig or bud of a fruit tree or an eye (bud) of a potato tuber cannot, as a rule, induce a change in the heredity of such offspring of the particular tree or tuber as do not derive directly from the changed parts of the parent organism. If we cut off this changed part and grow a separate, independent plant from it the latter will, as a rule, possess the changed heredity in full, i.e., the heredity of the changed part of the parent's body.

Should separate links in the general chain of development of a plant organism be unable to find the conditions their nature requires, the substances of the changed part of the body will perforce, as it were, be included wholly or partly in the chain of these processes and thereby participate in the development of the reproductive products. Therefore a change in the nature of separate parts of the body of a plant organism may leave the heredity of its offspring entirely unaffected, may affect it partly or, lastly, may be transmitted in its entirety. *The extent to which changes are transmitted will depend on the extent to which the substances of the changed part of the body have been included in the general chain of the process leading to the formation of reproductive sex or vegetative cells.* In nature this depends on the accidental conditions that the plant in question encounters, while in experiments and practical farming it depends on man's knowledge and skill.

It is a known fact that environmental conditions do not depend upon the different plant organisms. Organisms only possess definite requirements for various conditions. Whether the environment will contain these conditions, and whether they will be of the requisite quality, in the requisite quantity and at the requisite time, does not depend upon the plant. At the same time the life of plant organisms and the quantity and quality of their bodies depend upon the environmental conditions. As they say in practical farming: agrotechnique determines the quantity and quality of crops. As we have already indicated, with good agrotechnique and good conditions of cultivation plants may be obtained ten and even more times the weight and size of plants of the same variety (of the same breed) produced under exceedingly bad conditions. Here is a case in point. A millet plant which accidentally grew on a bare fallow weighed, with roots, stalks and panicles, 953 gr. Another millet plant of the same variety, which grew on a road near the field, weighed at the same stage of ripeness, together with roots, stalks and panicle, 0.9 gr., i.e., one plant was more than a thousand times as heavy as the other. Thus, although plant organisms possess the capacity to elect environmental conditions, nevertheless, since the latter are independent of the organism, and organisms build their bodies out of the environmental conditions, the result is that the body of the organism depends largely, in both quality and quantity, upon the conditions of life. Different conditions give rise to different plants and these differences are frequently very great.

How is it then that, in spite of the marked variability of the parent organisms, the development of particular organs and characters (both in the quantitative and qualitative sense) and the nature of the offspring, i.e., the heredity of these plants, remain rather stable, relatively unaltered?

Does this not argue in favour of the proposition that a change in the body of an organism does not entail a change in the nature, i.e., in the heredity, of this body? This is explained in part, as was pointed out above, by the fact that the changed parts of the body are frequently altogether excluded, or are included to a small extent only, in the metabolic relations with those links in the process as a result of which reproductive cells are obtained.

It must also be noted that not all processes in an organism, the development of not all organs and characters, are supplied with nutriment of the required quality and quantity in equal measure and with equal timeliness. Not all processes in an organism are of equal importance for the maintenance and propagation of the given species, strain or variety of plant.

It has already been stated that the characters and properties whose development does not substantially influence the life of the organism as a whole remain, as a rule, undeveloped, recessive, when there is a deficiency of the required environmental conditions. Let us add that when there is an excess of the required conditions these same characters develop, as a rule, likewise excessively, considerably above normal. In other words, the development of such characters is most variable, most fluctuating. But the characters or processes upon whose development the life of the organism as a whole largely depends vary less, fluctuate less.

If particular nutritive elements for the normal development of the entire plant are lacking, the first to starve, i.e., receive a subnormal quantity of food, will be the least essential organs, the least essential parts of the body. The processes that are more important to the organism will suffer to a smaller extent from an insufficiency of particular nutritive elements, and to a still smaller extent will those upon which the continued existence of the plant's race mostly depends. For instance, it is a well-known fact that if any farm animal is fed to excess it develops a thick layer of fatty tissue. If fed insufficiently the fatty tissue will not only cease to receive food but will itself be spent on feeding the other tissues of this organism. After the fatty tissue has been spent on feeding the organism, comes the turn of the muscular tissue, etc. In general, when animals starve the nervous and certain other tissues starve least. This is our explanation of why plants such as the two tufts of millet we took as examples, which were produced under sharply different conditions in point of nutrition and of which one exceeded the other more than a thousand times in size and weight, are far from completely transmitting these differences to their offspring.

The plants were nourished quite differently, but the nutrition of the separate parts, of the separate processes of those plants, departed from normal in various degrees. The main processes of the plant that had plenty of food were protected from an excess of it, the part above the norm being absorbed by other, less important processes. On the other hand, in the case of the plant which received insufficient nutrition, the main processes starved least of all.

Therefore, although the plants sharply differed in their development and departed in opposite directions from the norm, the processes upon which the continuation of the race depends most were fed quantitatively and qualitatively approximately according to the norm. After all, the size of the seeds taken from these two plants—plants which exhibited a thousandfold difference in weight—was almost exactly the same. Moreover, the embryos in these seeds, being the most important part, differed still less from each other. And, finally, the most essential parts of the embryos must have differed least of all.

Thus we give the following explanation for the absence of change in the heredity of the offspring when various characters or properties of the parent plants change or when these changes are not completely transmitted (as is most frequently the case).

Firstly: the active election of suitable environmental conditions by the various processes for the development of the various organs and characters, of the various particles of the living body.

Secondly: the active noninclusion of unsuitable conditions in the process. Parts of the body changed perforce do not fully include the specific substances they produce, and frequently do not include them at all, in the general chain of the process leading to the formation of reproductive cells.

Thirdly and lastly: in the organism, as in an integral whole, there is no "equalitarian tendency" supplying of the different processes with the requisite elements of food. The more important processes are supplied with greater approximation to the norm; they are protected against insufficiency as well as against a surplus of nutrition in general or of particular elements of it. Less important processes, on the other hand, are supplied less than the norm, the norm or more than the norm, depending upon the amount available.

The question may arise: wherein, then, does our understanding of the interconnection of the nature, of the heredity, of the organisms with the conditions of life differ from the point of view of the Morganist geneticists? The geneticists say that the conditions of life tend to cause only qualitative and quantitative changes of the body (soma) to the environmental conditions, but it must be remembered that the property of adaptability will not always be analogous to purposiveness. The relative purposiveness and harmonious nature of plants and animals in nature have come into existence only by natural selection, i.e., by heredity, its variation and survival.

When we know the way of building up the heredity of an organism we can change it without waiting for suitable occasions by creating definite conditions, definite action at a particular moment of the organism's development. The better we know the concrete laws of development of the various plant organisms the sooner and the more easily we shall obtain, create the requisite forms and varieties of these plants. Up to now good practical seed growers knew only that while good agrotechnique, the proper growing of seed plants, does not always improve their nature, it at any rate does not make them worse. On the other hand, bad growing conditions quite frequently, if not always, worsen the breed of varieties and never improve it. A knowledge, therefore, of the concrete laws of development of the nature of the plants in question offers the possibility of directing, of changing the nature of organisms in the required direction at any time, without waiting for chance.

VEGETATIVE HYBRIDS

Morganist geneticists conceive of an organism as consisting of the ordinary body, known to all, and a "hereditary substance," i.e., a body which they claim is known only to them (though not one of them has so far actually seen or felt this body). The first body (soma), the ordinary body, discharges various functions of the organism. It depends upon the conditions of life and changes when these conditions change. Secondly, the "hereditary substance," in the opinion of these geneticists, discharges only the function of reproducing the properties and characters of the preceding generations. Hence their definition of heredity as being only the property of an organism to reproduce beings similar to itself.

Our conception, on the contrary, is that the entire organism consists of only the ordinary body, known to all. The organism contains no special substance separate and apart from the ordinary body. But any particle, or, figuratively speaking, any granule, any droplet of the living body, once it is alive, must unfailingly possess the property of heredity, i.e., of requiring conditions suitable to its life, growth and development.

As we know, hybrids are organisms which possess the properties of two breeds, one maternal and the other paternal. In different cases particular properties of either parent predominate in the offspring in different degrees.

Hitherto sexual reproduction, the sexual union of the organisms of two breeds, was the sole method generally recognized by science of producing hybrids. Darwin and a number of other eminent biologists considered it possible to obtain also vegetative hybrids, by blending two breeds and obtaining a third, not only by means of crossbreeding but also by means of vegetative union. I. V. Michurin not only admitted the possibility of the existence of vegetative hybrids but also elaborated the mentor method. This method consists in grafting cuttings (twigs) of different varieties of fruit trees on the crown of a young variety whereby properties lacking in the latter are acquired by it, transmitted to it from the grafted twigs. This is why I. V. Michurin called this the mentor method, using mentor in the sense of trainer, improver. By this method Michurin produced many good new varieties and improved many existing ones. The Morganist geneticists of course do not deny but recognize the good varieties produced by Michurin. Yet they have refused to recognize the method of producing these varieties, and, in particular, the mentor method, i.e., vegetative hybridization, asserting, contrary to Michurin, that these varieties are obtained independently of the influence of the cuttings grafted on the crowns of the young varieties of trees possessing their own root systems.

Vegetative hybrids provide cogent proof of the correctness of our conception of heredity. At the same time they represent an insurmountable obstacle to the theory of the Mendelist-Morganists. This furthermore serves to explain why the Michurinists, who proceed from the facts and laws of objective living nature, recognize the possibility of existence of vegetative hybrids. The Mendelist-Morganist geneticists, however, deny this possibility.

The Michurinists, beginning with I. V. Michurin himself, have found methods of obtaining vegetative hybrids in large quantities. The Mendelist-Morganist geneticists, on the other hand, long denied the various cases of vegetative hybrids that had been known from time immemorial. Examples of vegetative hybrids, such as the *Cytisus Adami,* a cross between the hawthorn and the medlar, and others, were cited even by Darwin. But the geneticists considered all these cases to be not hybrids but so-called chimeras, by which they meant organisms in which the tissues of various breeds are vegetatively coalesced but not biologically blended. The geneticists used to assert that such organisms cannot sexually reproduce offspring with hybrid properties. But when the Michurinists during the last few years found a method of obtaining vegetative hybrids in large quantities and when these hybrids even in the seed offspring behaved like ordinary sexual hybrids, the geneticists could no longer find grounds for objection. They merely ignored these facts, at times calling them experimental errors. But they will not undertake to repeat these investigations for fear of obtaining vegetative hybrids.

Reference is frequently made to the generally known phenomenon that the grafting, on the most diverse stocks, of various breeds of fruit trees which in practice are propagated only in this way does not change the inherited properties of the grafted varieties. But in this instance it is forgotten that these varieties of fruit trees have already been fully formed, have already gone through their phasic development. Therefore they cannot suffer any change in those properties and qualities which long before, prior to the grafting, had completed their cycle of development. A different result is obtained when young varieties of fruit trees, which have not yet been fully formed, are grafted on. They, in such event, change, as a rule, the entire course of their further formation.

It should be known *that the whole process of development* of plant organisms, for instance, of annual cereals, *consists of separate successively connected processes, stages, phases of development successively passing from one to the other.*

It is easy enough to prove by experiment that, for instance, winter plants that have not completed the process called the vernalization phase cannot pass through all the processes subsequent to that phase. Besides, after going through the processes of the vernalization phase or, for instance, the next phase, namely, the photo phase, these plants will not pass a second time through the vernalization phase or the photo phase no matter how much they are propagated vegetatively by cuttings, i.e., tissues which developed from tissues that had already gone through the vernalization or the photo phase.

All this makes it clear that in practice *old, fully formed varieties of fruit trees can and should be propagated by grafting without any risk of losing or changing their good hereditary properties.* On the other hand, *organisms which phasically have not been fully formed,* which have not yet completed their cycle of development, *will always,* on being grafted, *change their development* in comparison with own-rooted, i.e., ungrafted, plants. Vegetative hybridization is not only of great importance to practical farming but also of considerable theoretical value as an aid to a correct understanding of one of the most important phenomena of nature—heredity. When we unite plants by means of grafting we obtain an organism of a different breed, namely, the breed of the scion and the stock. By sowing seed taken from either of the latter we can obtain offspring some of which will possess the properties not only of the breed from whose fruits the seeds were taken but also of the other breed with which the first was united by grafting.

Everybody knows that only plastic substances, saps, are interchanged between scion and stock. The scion and stock can interchange neither chromosomes of their cell nuclei nor protoplasm. Nevertheless, inheritable properties can be transmitted from stock to scion and reversely. Consequently, the *plastic substances elaborated by the scion and the stock also possess breed properties,* i.e., heredity. They posses the properties of the breed by which they are developed.

The numerous cases in which vegetative hybrids were obtained in recent years are clear proof of the incorrectness of the very basis of the Mendelist-Morganist theory, according to which heredity is possessed by only a certain special substance, separate and apart from the ordinary body and concentrated in the chromosomes of the cell nuclei. Any assertion that the property of heredity is bound up with some special, separate substance is wrong, in whatever part of the organism or cell it be located. *Every living particle or even droplet of a body (if the latter is liquid) possesses the property of heredity, i.e., the prop-*

erty of requiring relatively definite conditions for its life, growth and development.

Annual herbaceous plants provide very suitable material for the experimental production of vegetative hybrids with which to demonstrate that this is really a change of breed (a blend of two breeds) which can be transmitted from generation to generation also by sexual reproduction, i.e., through seeds, the same as with sexual hybrids. Tomato strains would be just right for the purpose. Two strains should be chosen, with sharp, clearly visible differences in, say, the colour of the fruits: red ripe fruits of one strain and yellow or white of another. The sharp difference may be expressed in the shape of the fruit, thus: round for one strain and pronouncedly elongated for the other; or in the structure of the leaves, thus: nondissected, like those of potato plants, and dissected, like the usual tomato leaf. Two strains may be taken, differing in the number of chambers and fruits—two-chambered and many-chambered, etc. Indicate the character whose alteration it is desired to follow up. For instance, the task may be assigned of converting the white colouring of ripe tomato fruits of the Albino variety into a red colouring and transmitting to the latter the character of the red-fruited variety; however this is to be done not sexually (by cross-breeding) but vegetatively, by grafting a cutting of a young Albino organism on the stem of a more mature plant of the red-fruited breed. The younger the plant whose characters it is desired to change the more successful the experiment will be. On the other hand, the plants from which it is desired to obtain a particular property or character should be older. Those of middle age will do best. Not less than 10-20 graftings should be made. They are quite easy to do and take little time. After the grafts have coalesced the best thing is to remove the twig leaves of the breed to be changed as often as possible. But the breed from which a particular character is to be taken, or transmitted, should be left as many leaves and twigs as possible. In order to make the experiment more exact, the flower buds on the grafted twig should be isolated during the flowering period by a gauze bag to protect them against insect-borne foreign pollen (though tomatoes are self-pollinators). In a number of cases in such experiments ripe fruits showing various degrees of colouring may already be obtained from the grafted twigs which, according to their breed, are characterized by white-coloured ripe fruits. After the fruits ripen the seeds should be taken from them, especially from the red ones, if there be such, and sown the following year. A number of plants from such a crop will, as a rule, bear fruits which, when ripe, will be tinted red. This colouring was transmitted by the graft component of the preceding generation through the plastic substances. The same thing may be observed with regard to any other character. For instance, seed offspring of the two-chambered variety of tomatoes obtained after it had been grafted on to a multichambered variety were multichambered without repeating the graftings. Nonerect, trailing forms, after being grafted on to erect forms, transmit the erect habit through the seeds to a considerable number of offspring. Shape of leaf, length of vegetative period (early maturity or late maturity), size of the fruits (big or small) and a number of other characters and properties were transmitted by heredity to seed offspring in the experiments performed by the Michurinists, scientific workers and experimenters.

It may now be asked: why do not all plants obtained from seeds of fruits of grafted twigs clearly manifest hybrid properties? Why is it that in a number of cases, though in the examples we have referred to this will rarely happen, one fails to discover even a single plant of the hybrid type? The following may serve as an answer. Plants of a hybrid type are not obtained in all cases because breeds and the various processes, in one and the same breed, as has already been stated, possess elective capacity, show preferences as regards their conditions of life, their food. It goes without saying that plastic substances elaborated by one breed are to some extent or other unsuitable, unfit to nourish the grafted component of the other breed. The grafted component may not take or assimilate them at all, or it may elect from all substances only those which suit it most and try to obtain all the rest from the leaves or from other parts of its own breed. This explains why as few leaves as possible should be left of the component whose breed it is desired to change.

The percentage of vegetative hybrids obtained will depend on the ability of the experimenter to compel, to coerce the grafted twig (cutting) to assimilate a maximum of the nutritive substances elaborated by the breed whose properties it is desired to transmit to the grafted breed. It is essential that the experimenter overcome the "unwillingness" (electivity) of the processes of the grafted twig to include these substances in the process of building its body.

The experiments we recommend will, as a rule, prove successful in a greater or smaller percentage of the plants. After performing them it will become clear to any geneticist still believing in the fundamentals of Mendelism-Morganism that this theory is not only fallacious but even pernicious if applied to practical pedigree-stock breeding and seed growing.

It should be emphasized that abroad in practical seed growing (including plant breeding) as well as in pedigree-stock breeding no use whatever is being made of the genetic theory. Good practical seed and pedigree-stock breeders have themselves worked out, through experiments and observations covering hundreds of years, ways and means of improving the old varieties of plants and breeds of animals, and also of rearing new ones. In foreign countries the science of genetics is divorced from practical farming, for which reason theory may develop there for many years in a wrong direction.

The vast factual material on the vegetative transmission of various characters of potatoes, tomatoes and a number of other plants with which the scientific staff under our direction had to operate has brought us to the conclusion that *vegetative hybrids do not differ in principle from sexually-propagated hybrids. Any character may be transmitted from one breed to another by grafting as well as sexual propagation.* The behaviour of vegetative hybrids in succeeding generation is likewise analogous to the behaviour of sexually-propagated hybrids. When sowing seeds of vegetative hybrids, for instance, of tomatoes (without further grafting), the hybrid properties of the plants of the preceding generation appear also in the plants of the subsequent generation. The phenomenon of segregation, as it is called, frequently met with in the offspring of sexual crosses, occurs also in the seed generations of vegetative hybrids. But what is observed much more frequently, and in a much higher degree, among the latter is so-called vegetative segregation, when the body of an organism is mosaic with regard to various characters.

An example of interest for purposes of demonstration is the grafting of white-fruited tomato cuttings upon red-fruited tomato plants. When the seeds were taken from the fruits of the white-fruited tomato twig the majority of the plants obtained in the first seed progeny bore red-coloured fruits. In a minority of the plants the fruits were white or slightly reddish. In the second seed generation the vast majority of the offspring of white-fruited plants was white-fruited. Only a few plants here and there yielded fruits which were more or less reddish. As a rule most of the offspring of red-fruited plants were red. But about 20-30% of them were white-fruited. In general the same diversity is observed as in experiments with analogous sexually-crossed tomato varieties.

Of special interest is the behaviour of the third seed generation sown in 1942 in Frunze (Kirghiz S.S.R.) by Comrade I. E. Glushchenko, a researcher of the Institute of Genetics of the Academy of Sciences of the U.S.S.R. The seeds of the second seed generation were taken from the Moscow sector of the Institute. *On some of the twigs of part of these plants the fruits obtained were red (pink), on others white.* There were several dozens of such plants. It is supposed that this property can be perpetuated and that a form of tomato is possible in which the same shrub will yield white, red and pink ripe fruits.

Vegetative hybrids deserve particular attention in studying the so-called destabilization of heredity. *They are exceedingly plastic material for the further building up of new breeds through the influence exerted by the conditions of cultivation.* Thus, for instance, the medium-maturing variety of tomatoes named Best of All, when grafted on the nightshade (a weed) brought about changes in a number of characters. A vegetative hybrid was obtained. Not one of the properties inherent in the Best of All variety of tomatoes remained unchanged. Comrade A. A. Avakian selected plants which even when propagated by seed produce fruits with vastly improved flavour. The shape of the tomato fruit variety taken for grafting also changed. The vegetative hybrids of these tomatoes produced forms which first acquired early maturity from the nightshade and subsequently, under the influence of the conditions of cultivation, became still earlier-maturing plants. We obtained the earliest cultivated tomatoes known to us. When these forms were seed-

Moreover, this body will resemble in one degree or another the properties of the breed which elaborated the particular plastic substances. However, the new body in question will differ to a great extent from that breed. After all, the plastic substances of the red-fruited breed were assimilated by the white-fruited breed differently from the way the red-fruited breed usually assimilates them. Each breed builds its body in its own way. The given example shows how *the living body, by assimilating this or that food, changes itself biologically. These changes consist in the acquisition of requirements for the conditions assimilated by the body.*

In vegetative hybridization experiments the scion receives its food from the twigs and roots of the stock. A scion has no roots of its own and most of its leaves are frequently gone (artificially removed). Usually, however, a plant obtains its food from its external, nonliving environment. The nutritive elements are extracted by the organism from the environment electively. Only what is suitable to the nature, the heredity of the particular organism is taken. In the absence of suitable conditions the organism is frequently compelled, as in vegetative hybridization, to assimilate more or less unsuitable conditions. Hence a body of a different structure is obtained. The latter requires for its growth and development conditions which have been assimilated for the first time, and perforce at that

When the changed seeds of the vegetative hybrid obtained on a grafted twig are sown in beds, they elect from the external environment the conditions which in the final analysis are necessary for building the particular organism's body. This body, however, is similar to the body first obtained as the result of the grafting, i.e., owing to the enforced assimilation of unsuitable conditions.

Thus if the scion was compelled to assimilate the plastic substances on account of which, as a result of a number of biochemical transformations, the ripe tomatoes obtained are red, the sown seeds from these fruits will have a tendency to elect from the external environment all the conditions which, in sum, after numerous regular conversions, will yield ripe fruits of a red colouring.

Thus, *being an external element—food—with regard to the scion, the plastic substances of the stock, after becoming a component part of the scion's body by means of assimilation, change the scion's hereditary properties.*

By analogy, as we see things, *the elements of inanimate nature, too, pass by means of an assimilation which frequently is enforced from the plant's external environment to the component parts of the living body, become living elements and acquire the property of heredity.* In future generations these external conditions are required by the living, developing body for the reproduction of bodies similar to itself.

These new elements of food are now required by the living body as a result of the processes that took place in the preceding generations, in consequence of the incorporation of the new element of the external environment. *As the inanimate elements of nature are assimilated by the living body they cease to be what they were not only externally but also in the strictly chemical sense.* At the same time they acquire a *pronounced biochemical affinity for, a gravitation* toward, that form of the elements of the external which was inherent in them before the living body had assimilated them, before they had been transformed into that particular living form.

By now much experimental material has accumulated which demonstrates the possibility of directive change in the heredity of plant organisms by bringing the conditions of life, the environmental conditions, to bear upon it accordingly. *Vegetative hybrids are*, in science, a transition stage, as it were, *an intermediate link between changing the heredity of plant organisms by crossbreeding and altering heredity by bringing the conditions of life to bear on the organism.*

The theoretical significance of mastering the process of obtaining vegetative hybrids is obvious. These hybrids clearly show that *the heredity of plant organisms can be changed by changing their nourishment.* More. The *changes obtained correspond, are adequate, to the action of the external environmental conditions.* Thus the action of the plastic substances of the red-fruited breed of tomatoes changes the white-fruited breed to the red-fruited breed.

The action of the plastic substances of a tomato breed with leaves resembling those of the potato plant changes the breed with dissected leaves into a breed with potato leaves, etc.

ABOLITION OF THE CONSERVATISM OF THE NATURE OF ORGANISMS

Our conception of the phenomenon of heredity enables us, through the action of environmental conditions upon plants, to elaborate methods of directively changing the nature of plant organisms, of enhancing their adaptation to conditions of cultivation in the fields. Thus, owing to their heredity, winter cereal plants cannot become vernalized, go through one of the phases of its development, if sown in spring when there is no lengthy period of low temperatures. Hence they cannot bear fruit. But there are two ways by which they can be compelled to do so. The first way is to supply the winter plants with suitable low temperature conditions (approximately 0°-10° C. above zero) for 30-50 days, depending upon the variety. After this the winter plants will be able to continue and complete their development under the usual spring and summer field conditions. The second way is to alter their nature, after which they will cease to be winter plants with regard to their heredity. In both cases the change in the development of winter plants in spring sowings must be brought about by the action of the corresponding thermal conditions. They will differ only in the following. In the first case when vernalizing the winter variety, plants or seeds that have just begun to germinate are afforded the low temperature required by the nature of these organisms. Therefore the process of vernalization goes on normally for the development of the winter plants. The changes are the usual ontogenetic ones (growth changes). The seeds of a crop of such plants have the same heredity; they will possess the same winter habit as the seeds of the preceding generation. In the second case, at a certain moment during the passage through the phase of vernalization, the plants are afforded not the low temperature (near 0°C.) which they require for that particular process but the usual spring temperature. Two alternative possibilities arise: either the process of vernalization will not take place altogether, the plants will not complete, will not go through, the process of vernalization for lack of the requisite thermal conditions and will therefore be unable to develop further; or the process of vernalization will take place, but under rather unsuitable thermal conditions. These changed thermal conditions will cause the process of vernalization to be completed differently from the way it would under normal conditions, i.e., when the temperature is low. It goes without saying that with the change in the process there will also be a change in the body, which is the result of this process. The entire further development of this body, though in external appearance indistinguishable from the development of the usual, normal unchanged plants, will be different, as can readily be observed in the plants of the following generation. In order to pass through the phase of vernalization the next generation's plants will tend to elect the conditions which were forced on the previous generation. Instead of winter plants, plants with a tendency toward the spring habit will be obtained.

In the experiments relating to this question made in laboratories under our supervision by Comrade A. A. Avakian and other scientific workers of the All-Union Institute of Selection and Genetics, many hereditary spring forms have been obtained from winter forms. Hereditary spring forms have been obtained from all standard varieties of winter wheat experimented on. On the other hand, quite a number of spring forms of wheat and barley have been converted into hereditary winter forms.

From the point of view of mastering the process of directing changes in the nature of organisms, experiments in the conversion of winter forms into spring forms are of greater interest to the experimenter than the conversion of spring forms into winter forms. Experiments of the first kind are more convenient to perform and the results are more easily ascertained. One need only sow in spring the seeds taken from the experimental plants and the results are at once apparent. All plants which ear normally clearly indicate that their hereditary winter habit has already been altered to the spring habit. However, in experiments made to convert spring forms into winter forms it is difficult to discover changes even where the sowing material had been deliberately changed. When such material is sown in spring the experimental plants will be practically no different from the usual, unchanged spring forms because the acquired tendency toward the winter habit was not fixed. They will ear. If sown in autumn, a change in their nature will likewise be difficult to perceive even if the experimental plants pass the winter. After all, in many cases even ordinary spring plants can endure winter in the absence of severe frosts. But when there are such frosts the slight conversion of spring forms into winter forms seldom saves these plants from the devastating effect of winter. The changes must be more powerful, but this can be accomplished only over several generations

Experiments in the conversion of spring forms of grains into winter forms are, however, of great practical interest for obtaining winter-hardy varieties. There already are a number of winter forms of wheat and barley which were obtained from spring forms by means of training, by bringing the environment to bear on them. These forms are not inferior, and some are even superior, in point of forst resistance, to the most frost-resistant varieties used in practical farming.

The science of agrobiology is confronted with the task of elaborating more and more concrete methods of altering the heredity of plant organisms in the direction we desire.

Let us briefly set forth the technique of transforming, through the action of environmental conditions, hereditary winter forms of cereals into spring forms and spring forms into winter forms. Winter forms, as is known, require a lengthy period of low thermal conditions to pass through the phase of vernalization. Spring forms do not require such conditions.

In order to transform winter forms into hereditary spring forms the process of vernalization of winter forms must be acted upon not by low (near 0°C.) temperatures but by the higher temperatures that occur in the fields in spring. According to our thesis, if a change in the processes takes place it will be adequate to the influence exerted.

In the next generation all processes of development must be gone through anew, as it were, in the same form in which they went on in the preceding generation. In the preceding generation, when not a low but a high temperature acted on the process of vernalization of winter forms, the process changed in accordance with the action of the temperature. Consequently, in the next succeeding generation the process of vernalization, which in the previous generation was traversed under the action of a higher temperature, will require the same conditions (a high temperature). This general proposition has been shown to be true in many experiments performed by us and many other scientific workers. However, despite the correctness of this general proposition, the desired result is not certain to be achieved in every particular case. The concrete possibilities and methods of altering the nature of organisms must still be worked out separately in each individual case.

In order to change winter plants to spring plants it is necessary to bring a high temperature to bear upon the process of the vernalization phase. But we know that in winter plants the process of vernalization does not take place when the temperature is high, or at least takes place very slowly. Winter wheat plants and the winter plants of other cultures can grow for months under a high temperature without going through vernalization and consequently without changing this process.

In practice many varieties of winter plants have been sown for many years on large areas in the beginning or middle of August, i.e., long before the cold winter weather sets in. The lower autumn temperatures usually set in a month or two after the sowing season. Yet in crops thus sown winter plants never turn into spring plants. Experimentally, too, winter plants can be kept for many months in a warm place (a greenhouse) but all the time they will look like grass. They will not be able to become vernalized, will not come into ears. Consequently, the process of vernalization did not change when the temperature was raised. Winter plants do not ear in the absence of the low temperatures they require for the phase of vernalization.

One may arrive at the erroneous conclusion (and the geneticists not infrequently do so) that it is impossible to direct changes in the nature of organisms by bringing conditions of life to bear upon it. As a matter of fact, however, as our numerous experiments have shown, winter plants can be converted into hereditary spring plants. Moreover, such *conversion takes place only as a result of the action of high temperatures upon the process of vernalization*, i.e., such temperatures as usually prevail in the fields in spring. The cases in which winter plants are kept for a long time under high thermal conditions and no change in heredity is obtained merely go to show that the plants, or rather their process of vernalization, did not respond to these conditions.

In the example we are analyzing, the plant organisms failed to respond to the influence brought to bear upon them because of the conservatism of heredity. The experimenter is therefore confronted with the task of finding better methods that will make it possible to induce the required action. A method already exists whereby a certain percentage of a hereditary spring form may be obtained from hereditary winter forms of any variety of cereals.

Experimental data and also a number of general biological observations have led us to conclude that *relatively high thermal conditions should be brought to bear on plants of winter habit with the aim of converting their heredity* *into that of spring habit not at the beginning of the process of vernalization* (and in general at no time during the process) *but only at the end, upon its completion.* This is what success in bringing influence to bear hinges upon.

The usual duration of the process of vernalization in most winter grains, given low (0° to 2°C.) thermal conditions, is 30-50 days, depending upon the variety.

The winter plants must be enabled to go through the process of vernalization at low temperatures, i.e., at temperatures suitable to their heredity. But just before the process of vernalization ends, higher thermal conditions must be created, the plants must be provided with the usual spring conditions. Usually the process of vernalization does not take place in winter plants when the temperature is high. But if high thermal conditions are created just before the completion of the vernalization process the plants will finish this process, though slowly and painfully, if one may say so. All further development will proceed normally since in spring and summer the environmental conditions in the fields are suitable for this development.

Experiments in the conversion of winter plants into spring plants were carried on as follows. Seeds of a winter variety were taken and, before spring field sowings became possible, different portions of these seeds were vernalized for different numbers of days at temperatures usual for winter plants. One sample of seeds was vernalized for 5 days before it was sown in the fields, another for 10 days, a third for 15, etc., up to 40-50 days. All these seeds vernalized to different degrees were separately sown in the fields in beds at one and the same time early in spring. The plants grown from the samples of seeds that had been completely vernalized before being sown in the fields developed normally, without delay on account of the vernalization stage (since that had already been gone through); they produced straws and spikes. However, the plants obtained from samples that did not quite complete the process of vernalization before they are sown finish it quickly if low temperatures prevail for a relatively long period under field conditions after the sowing in spring. If that is not the case the plants grown from seeds that were not completely vernalized before the sowing will be slow to finish the vernalization process. Such plants likewise ear, but with more or less delay. These plants are the most interesting for the purposes of the above-mentioned experiment. It is from them that one most frequently succeeds in obtaining hereditary spring forms. Further work along the line of obtaining spring forms from winter forms therefore requires that the seeds be taken from samples of plants not completely vernalized before the sowing but which finish the process of vernalization after the sowing, in spring, under field conditions. From the seeds of such winter plants one can obtain a certain percentage of hereditary spring forms. This was the way many spring forms were obtained from all the winter varieties of wheat experimented with at the Institute of Selection and Genetics of the Lenin Academy of Agricultural Sciences of the U.S.S.R.

It is thus clear that the hereditary winter habit can be changed to the spring habit. This change can be brought about by the action of high temperatures that suit the heredity of the vernalization stage of cereal forms called spring plants. This corroborates the correctness of the general proposition that *a change in the heredity of any property corresponds to the action of the external environmental conditions.*

As has already been stated, not all seeds obtained from grafted plants produce hybrid plants. The percentage of hybrid plants secured depends on the ability of the experimenter to overcome the resistance of the grafted breed and compel it to assimilate plastic substances to which it is unaccustomed. Analogously, spring plants will not be obtained from all seeds of winter-wheat plants taken from parent samples which were known to have assimilated. i.e., finished, vernalization under high, spring temperature conditions.

In the majority of such cases what happens is something very much like the behaviour, during the spring sowing, of plants obtained from the usual, unchanged winter seeds. This takes place because when sowing seeds even from plants known to have been changed with regard to the vernalization stage one frequently obtains plants which do not yield spikes if sown in spring.

Thus, in the spring of 1936, three winter varieties of wheat were drill-sown in the fields of the Odessa Institute of Selection and Genetics; the seeds were of the usual, unvernalized kind. It was an early spring, long and cool. Usually when winter plants are sown in spring they either do not ear at all that summer or ear very sparsely and late in the season. But the plants of the above crop of all three varieties (Novokrymka 0204, Kooperatorka and Stepnyachka) eared uniformly though late, and yielded a fairly good harvest. The seeds of all three varieties of this crop were drill-sown again in the spring of 1937 in the open field without prior vernalization. As a variant of this experiment, seeds of the varieties in question taken from ordinary winter crops were all sown at the same time in one locality. One would expect that the plants of the winter variety obtained from seeds of the crop planted in the spring of the preceding year (without pre-sowing vernalization) should in the new generation (the 1937 spring sowing) ear more uniformly, produce a greater percentage of eared plants in comparison with the second variant. In actual fact, however, the opposite proved to be the case. With regard to all three varieties the plants obtained from seeds sown in spring for the first time yielded a percentage of eared plants which, on the whole, was small. Besides, the earing was much delayed. Yet the percentage was considerably greater than that obtained from the seeds resown in spring. However, the plants from the seeds sown the second time in spring eared much earlier.

The result of this experiment patently demonstrates that the unusual termination of the process of vernalization in the winter plants of the 1936 spring sowing by the use of unvernalized seeds definitely changed the nature of the winter plants. At first sight it may seem that the change which occurred was not in the direction of the spring habit, as it should have been, but in the direction of a still greater winter habit. After all, a smaller percentage of earing plants was obtained on the plots sown in 1937 with these seeds than on the plots sown with seeds of the same varieties, but with seeds sown for the first time. As a matter of fact the change in the vernalization stage of plants of the 1936 sowing under analysis proceeded in the direction of lessening the winter habit (the requirement that the process of vernalization be traversed at low temperatures). But many experiments show that when the old, long-established property of heredity, in the case under examination the property of winter habit, is abolished, no established new heredity (in our case, the spring habit) has as yet been obtained. *In the vast majority of such cases one obtains plants possessing a so-called destabilized heredity.*

Plant organisms are said to have a *destabilized heredity* when *their conservatism has been abolished, when their capacity to elect external environmental conditions has been weakened.* Such plants, instead of retaining their conservative heredity, retain, or newly exhibit, only a tendency to give preference to some conditions over others.

Heredity can be *destabilized* in the following way:

1) *by grafting*, i.e., by uniting the tissues of plants of different varieties;

2) *by subjecting plants to the influence* of the environment at definite moments when they are undergoing *developmental processes of one kind or another*;

3) *by crossbreeding,* particularly of forms sharply differing in habitat or origin.

Much attention was paid by some of the best biologists—Burbank, Vilmorin, and particularly

Michurin—to the practical value of plant organisms with destabilized heredity. Plastic plant forms with unestablished heredity, obtained in this or that way, must be planted from generation to generation under conditions the requirement or stabilization of which are to be induced in the particular organisms.

Usually when a plant with a nondestabilized heredity lacks the conditions necessary for some process to take place, as, for instance, when the low thermal conditions required for the vernalization stage of winter plants are lacking, the process does not take place. The plant waits, as it were, for the requisite conditions to arrive. If the temperature drops at night the autumn-sown winter plants go through the vernalization stage. If the temperature rises in daytime the vernalization process stops until a lower temperature sets in, even if the interval lasts many days.

But organisms whose heredity is destabilized, as for instance the progeny of the winter plants whose vernalization stage was completed not under low but under high, spring temperature conditions, do not possess an established heredity (requirement) but only a tendency to the conditions under which the vernalization process of the plants of the preceding generation was completed. If no such temperature sets in, the process will not wait but will take place under whatever temperature there is. Ordinarily, in the field, thermal and many other conditions, as a rule, vary, fluctuate. *Owing to the conservatism of their heredities plant organisms stubbornly and unswervingly elect from their varying, fluctuating environment only what is needed for particular processes to take place.* But if the heredity is destabilized, not fixed, the process fluctuates, moves in various directions, as they say. When the temperature is low it goes in one direction; when a higher temperature sets in, it takes another direction. As a result the process is not coordinated. This explains the cases of failure to ear when winter wheat whose vernalization stage has been deliberately changed is sown in spring. They remain in the tillering phase not on account of their winter habit but because the different directions which the vernalization process takes make it impossible in these cases for the process to be completed.

For plants with changed, destabilized heredity the conditions of cultivation must be selected with skill. It must be remembered that these plants are frequently most susceptible to environmental conditions. Therefore it is necessary to provide, as far as possible, the conditions toward which it is desired to direct, to fix the heredity.

In nature the evolution of plants and animals proceeds through random changes in the old he-

redity, through the fortuitous building and fixation of a new heredity. In experimental as well as in practical farming the heredity of particular processes of plant and animal organisms can be made to undergo a directed change, and the building and perpetuation of the new heredity can be directed.

To obtain hereditary spring forms from the seeds of destabilized winter plants, i.e., such as completed the vernalization stage at high temperatures, they must be sown in the field in spring at different dates, the first as early as possible. This will make it possible for the vernalization process of the plants of this or that sowing date to coincide with the environmental conditions toward which they tend. Such plants ear quickly. The seeds taken from them will, as a rule, in their vast majority, produce offspring closely akin in behaviour to the spring forms. But the heredity of such forms will still be fixed to only a small extent. If the sowing conditions in spring are unusual (for instance, if the spring is too protracted and cold or too hot and short) these plants may deviate from the more or less established spring form of life. In general, after changing the heredity of the winter plants by bringing the spring thermal conditions to bear on the vernalization process at the time of its completion, the heredity of the spring habit must be fixed over a period of two or three generations. Only thereafter will the form be really established.

For practical purposes great importance attaches in a number of districts of the U.S.S.R. to the conversion of spring cereal forms into winter-hardy winter forms and winter forms into more hardy, more frost-resistant forms. These experiments in no wise differ in principle from the experimental work performed in the cases already discussed relating to the conversion of winter plants into spring plants. Hereditary spring varieties are changed into winter varieties by sowing them late in the autumn. The spring forms of cereals are provided with low thermal conditions at the time they go through the vernalization process, a long period (autumn, winter and early spring). A repeated sowing of the seeds obtained from these plants in late autumn fortifies the new property of winter habit. Their requirement of low thermal conditions for the vernalization process is enhanced.

As the succeeding generations are sown from year to year under increasingly severe wintering conditions, cereal plants with still unestablished (destabilized) heredity of the vernalization stage will require low temperatures to an ever-increasing degree. They will acquire the property of increasing resistance to severe frosts. At present we have a number of good forms of winter wheat obtained by various experimenters from spring wheats. These new forms are no less frost-resistant than the winter variety Lutescens 0329 of the Saratov Plant-Breeding Station, which is so far considered the most frost-resistant of all wheats.

A. F. Kotov and N. K. Shimansky, research workers of the Institute of Selection and Genetics, obtained after several generations a winter form of wheat from the spring form Erythrospermum 1160 by means of late, prewinter sowing. When sown at the experimental base of the Lenin Academy of Agricultural Sciences of the U.S.S.R. at Gorki Leninskiye, Moscow Region, and also on the experimental plots of the Krasnoufa, Barnaul and Semipalatinsk plant-breeding stations and elsewhere, this form proved itself a promising variety for these districts.

A point of interest here is the fact that the seeds of this wheat distributed in the autumn of 1940 among the places indicated all came from one bag. But since this wheat is not yet established, is still highly plastic, it deviated at each place where it was grown in the direction of the conditions of life, of the conditions of cultivation. The conditions prevailing in each locality left their imprint upon this plastic, pliant form of plant. Under the severe wintering conditions in the districts of Siberia this wheat is becoming each year more and more frost-resistant, winter-hardy.

Comrade A. A. Avakian converted spring wheat Lutescens 1163 bred at the Institute of Selection and Genetics into a winter wheat by sowing it late in autumn. Today this wheat comes close to the most frost-resistant winter varieties in regard to its resistance to the inclemencies of winter. A number of wheats which in this respect excel the most frost-resistant Lutescens 0329 were obtained by converting natural Siberian windfalls of spring wheats into winter wheats. Thus, the wheat harvested by the kolkhoznik Sekisov (Michurin Kolkhoz, Barnaul District, Altai Territory) already far surpasses the Saratov Lutescens 0329 in frost resistance. A number of other forms of winter wheat obtained from spring windfalls in Siberian plant-breeding stations also represent exceedingly promising material for growing highly winter-hardy varieties.

Comrade Solovey, a scientific worker, obtained a winter form by the late autumn sowing of spring barley Pallidum 032 of the Odessa Station. Owing to the plasticity of this form it proved to be readily adaptable to rather severe wintering conditions. In our opinion this barley is now one of the most winter-hardy varieties among all the winter barleys known to us. It has already withstood quite well two winterings on a section of the experimental base of the Academy of Agricultural Sciences at Gorki Leninskiye, near Moscow, and also at the Kazan State Plant-Breeding Station. Ordinary winter barleys do not survive the winter in these regions.

The most interesting thing for practical farming in these experiments is the fact that it is quite easy to increase from year to year the resistance of the above wheat and barley forms to frost and other tribulations of winter. Unestablished forms, forms not yet consolidated after their heredity was destabilized, can easily be altered to acquire increased resistance by bringing more and more severe wintering conditions to bear on them with each passing generation. The properties acquired from generation to generation will become more and more fixed. But the acquired properties can easily be lost if the material still unestablished during the first few generations is not handled skilfully. Let us cite the following instance. The winter barley which, as already stated, Comrade Solovey obtained from spring variety Pallidum 032 when sowing it in experimental plots located in the central zone of the Soviet Union has proved to be the most winter-hardy of all winter barleys we know of. In the spring of 1940 some plots of the All-Union Agricultural Exhibition were sown with samples of this barley. For some time it behaved like a winter form. The plants trailed on the ground; no straw (flowering shoots) developed. It was assumed that, being a winter form, the plants of this barley could not pass through the vernalization stage under spring thermal conditions. However, as afterwards appeared, all plants on this 100-metre plot rapidly formed flowering shoots, eared well and yielded a good crop. This indicates that the heredity of the winter habit had not yet become consolidated in this form of barley. Having been sown in spring and having waited a while for cool thermal conditions to set in, which naturally did not happen, the plants went through a new type of vernalization, i.e., became vernalized as spring plants. The seeds harvested from these plants were sown in the autumn of the same year, 1940, by Comrade Avakian on plots located at the experimental base of the Lenin Academy of Agricultural Sciences of the U.S.S.R. near Moscow. At the same time seeds of this variety taken from the exhibition sector of the 1939 autumn sowing were planted. It appeared that the plants from the spring-sown seeds of the preceding year withstood the winter of 1940-41 incomparably worse than the variant obtained from the seeds of the crop sown in the autumn of 1939. The cultivation of only one generation of plants of the indicated barley variety under the conditions of spring sowing considerably weakened the property of winter hardiness of the offspring of these plants. On the basis of this example we showed that *plastic,* *unestablished plant forms obtained in one way or another should be sown from generation to generation only under conditions the requirement or stability of which, the hardiness with regard to which, must be induced in the particular plants.*

Plant organisms that are not yet established in regard to their heredity, which are still destabilized, are in many cases very valuable material for the creation, by appropriate training, of forms and varieties we need. At the present time progress is being made in the creation of winter-hardy varieties of winter wheat for the districts of Siberia with their severe winters. Already noteworthy results have been achieved. Spring wheats that possess no winter hardiness whatever are being converted, by means of destabilization, of altering the vernalization stage, into frost-resistant wheats. Winter wheats are being converted in this way at Siberian plant-breeding stations into wheats of increased winter hardiness, of greater winter habit.

THE SEXUAL PROCESS

The sexual process is one of the most important in wild plant and animal organisms. All other processes are in actual fact subordinate to it. Animals and the vast majority of plants reproduce sexually.

When plant organisms are propagated asexually, vegetatively—by means of tubers, cuttings, buds, etc.—these plants do not begin to develop de novo. They continue to develop from the stage reached by the tissue taken as the basis of the new organism. *The sex cells, on the other hand, provide a new basis of development, which in many cases completely repeats all alterations and conversions undergone in the preceding generations.* This property distinguishes the sex cells in principle from all others that can serve as the basis of an organism. When plant organisms develop from seeds one can easily observe how the tissue of the developing organism changes qualitatively, beginning with the fertilized sex cell, how through a number of regular alterations and conversions ever new cells are created, tissues with their specific properties are differentiated and various organs develop. In general an ever new quality of the cells of the organism is obtained This quality is capable of being converted into a further quality, a new quality predetermined, as it were, by its ancestors. But it is incapable of being converted into the old quality, the quality of the preceding cells that gave rise to the present ones. The sex cells, however, while new with regard to the asexual cells from which they in the final analysis were formed, are at the same time largely and frequently exactly like the initial sex cells, i.e., the old cells from which the entire development of the organism in question started. *The sex cells represent the completion of the organism's cycle of development.* At the same time *they are the beginning of the development of new organisms.*

In this light the great biological significance of the sexual process in the evolution of plant and animal forms becomes intelligible.

Natural *hereditary changes*, departures from the norm in plants and animals *are*, as a rule, *enforced changes. They take place because the conditions of life are not suited to the developmental requirements of the various organs, characters and processes* in general of plant and animal organisms. It has already been pointed out that in sexual propagation development begins de novo. Therefore *conditions which were inappropriate, unsuitable to a particular process of the preceding forms, become normal and requisite for the new generation.*

Changes in the conditions of life, in environmental conditions, are, as a rule, independent of specific animal and plant forms. If plants and animals possessed the properties of infinite individual life they would, in popular language, be having a hard time of it all their lives. The external conditions, which are always changing at one time or other, would never suit, correspond to the requirements of the organisms. In other words, owing to changes in climate and in the conditions of life in general, organisms with very prolonged individual lives are inconceivable in free nature. Evolution, the increasing complexity of plant and animal forms, is possible only because all living forms have a succession of generations. It is a very noticeable fact that the shorter the normal individual life of plants and animals the greater adaptability to the changing environmental conditions which the species of these organisms possess. Microorganisms with brief spans of individual life adapt themselves to the changing conditions of life most easily.

Another very important biological property of sex cells may be reduced to the following: *The sex cell is biologically* (but not chemically) *the most complex of cells.* In it the potential hereditary properties inherent in the whole organism are expressed in a higher degree than in any other cell of the organism.

The entire course of development traversed by the organisms of the preceding generations is accumulated, as it were, in the sex cells. From these cells development starts de novo. What takes place may be described as the unwinding from within of a chain of numerous changes and conversions which were wound up in preceding generations. We have already pointed out that this unwinding of past processes goes on only by winding up the processes for the future generation. The development takes place solely through metabolism, through assimilation and dissimilation, and this is the creation of the foundations of the future generation.

In the vast majority of plants and animals new organisms arise only after fertilization—the fusion of male and female sex cells. The biological significance of the processes of fertilization consists in the fact that organisms with a dual heredity are obtained, maternal and paternal. *The dual heredity calls forth greater vitality* (in the direct sense of the word) *of the organisms and greater adaptability to the varying conditions of life.*

The internal forces, the properties of the body itself to live, to be altered and transformed, constitute the impulse of development. Much practical and experimental material can be offered as cogent proof that fertilization, the crossbreeding of even slightly differing forms of plants or animals, produces more viable offspring. Conversely, prolonged self-fertilization, self-pollination in plants and the pairing of closely-related animals leads to an attenuation of life. Normal vital internal contradictions, the vital impulse, is created, and likewise is renovated from time to time in the plant and animal world in the vast majority of cases by means of crossing, of fertilization, by means of a sexual union of forms of plants and animals which differ at least slightly from each other.

All ordinary (asexual) cells divide in two upon completing their development; this is the way cells multiply and the body grows. *However, sex cells* not only *do not divide* in two upon completing their development but, on the contrary, normaly *from two sex cells*—a female and a male—*one cell is obtained, usually a more viable one* than any of the other cells.

Both the female and the male sex cells fully possess the properties of their breeds. Breeds differ to a greater or smaller extent. After the zygote is obtained, i.e., after the female sex cell is fertilized, a single cell is formed, the basis of the organism in which all the breed properties of both initial forms are represented. It is on the basis of the contradiction arising between the two united but relatively different sex cells that the internal vital energy, the property tending to alteration and conversion, arises and gains in intensity. It is this that determines the biological necessity of crossing forms that are at least slightly different from each other. Darwin repeatedly emphasized in his works that the usefulness of crossbreeding and the biological harm of self-fertilization are a law of nature.

Renovation, intensification of vitality of plant forms, can also proceed in a vegetative, asexual way. It is attained by the living body assimilating new environmental conditions that are unusual for it. Such cases are usually rarer in nature. Nevertheless, a number of plant forms might be cited which for a lengthy period, actually for the duration of all time known to history, have been reproducing vegetatively only and all the same are not losing their vitality, their internal impulse. In experiments in vegetative hybridization, either to obtain spring forms from winter ones or winter forms from spring ones, and in a number of other cases of the destabilization of heredity, one may observe a renovation, an intensification of the life of organisms by the inclusion in their bodies of new conditions that are unusual for them.

The conception of the process of fertilization generally accepted in the science of genetics seems wrong to us in many respects. Cytogeneticists draw their picture of the processes of fertilization from looking into the microscope at the slide where cells in various states of development have been fixed. Everything visible is jotted down and what is not visible is drawn from imagination, is conjectured in the light of the conception, the theory of heredity propounded by the Mendelist-Morganists. The cytogeneticists proceed from the idea that heredity is a special substance different from the ordinary body and contained in the chromosomes of the cell nuclei. According to their conception the heredity confined in the chromosomes of the male sex cell nucleus and the heredity concentrated in the chromosomes of the female sex cell nucleus unite mechanically to form a single cell. The chromosome substances do not blend either in the biological or even the chemical sense. The chromosomes in the male sex cell introduced into the nucleus of the female sex cell remain there in the form in which they were and still are in the cells of the paternal organism. This postulation of the cytogeneticists is based on the fact that some time after fertilization double the number of chromosomes—the sum of the chromosomes of the female and the male sex cells—are observed under the microscope in the zygote (the fertilized sex cell). The entire conception of the process of fertilization has been built up by the cytogeneticists on this notion. Such a conception is absolutely unacceptable, especially to biologists. It corresponds neither to the sexual process nor in general to any biological process whatsoever that goes on in the living body.

Already Darwin pointed out that when vegetative hybrids become possible, physiologists will have to change their views on the sexual process radically. In actual fact, in the light of the mass of factual material on vegetative hybridization, the question of the essence of the fertilization process must be stated anew. In the first place fertilization—the union of two cells in one—is not a simple fusion of two cells physically not even soluble in each other. There is not a single normal process in the living body which does not represent an alteration or conversion, i.e., which is not an assimilation-dissimilation reaction.

The Mendelist-Morganists have actually taken away from the physiologists, and the latter have turned over to them, the examination of the problem of fertilization. All processes in the organism are transformations—metabolism. The process of fertilization is the only exception, in the opinion of formal science, and therefore the examination of it is not within the purview of physiologists. The geneticists deny that the sexual process is metabolism, is a process of assimilation and dissimilation. According to the conception entertained by the geneticists a special body, the hereditary substance, is concentrated in the chromosomes of the cells. The laws governing the life of this body are different from those governing the ordinary body. The hereditary substance is not subject to ordinary metabolism; nothing can be included in or excluded from it. The hereditary substance is transmitted unchanged from generation to generation. In rare instances it may be lost, may perish; in rare instance, for unknown reasons, it appears de novo (mutations). Heredity is concentrated in the nuclei of the sex cells. That explains why the study of the development of sex cell nuclei has passed, during the last few decades, into the hands of the formal science of heredity, into the hands of the Mendelist-Morganists.

The numerous experiments performed during the last few years in the mass production of vegetative hybrids, and the transmission of their properties to their progeny sexually, fully entitle us to regard fertilization as an ordinary physiological process. Like any biological process, fertilization, the union of two sex cells, may be reduced to assimilation and dissimilation.

The fundamental distinction between fertilization and all other biological processes is as follows. In any physiological process one of its aspects assimilates, the other is assimilated. The assimilating body builds itself from food, starting with the elements drawn by plants from the external environment and ending with ready plastic substances. The assimilated substances serve as building material for the assimilating component. In the sexual process, however, when two cells of equal standing, so to say, unite, they mutually assimilate each other. Each one builds itself in its own way from the substance of the other. *In the final analysis neither of the two cells remains and a third, a new one, is obtained, one in place of the two.*

The Mendelist geneticists hold up the allegedly always existing multiple relations in the variation of hybrid offspring in the second and later generations as one of the principal proofs that heredity is particulate (corpuscular). They ascribe to each character and property of a living body a certain number of particles (genes) of the hereditary substance located in the chromosomes.

In fertilization, when two sex cells unite for every property, a double set of particles is obtained in the fertilized sex cell: one paternal and the other maternal.

To make this clear let us cite the classical example of Mendelist geneticism, the crossing of two forms of peas which differ, for instance, in the colour of their blossoms. Chromosomes containing particles (genes) of the hereditary substance which determine the red colour unite on fertilization in one nucleus with chromosomes containing genes of white-coloured blossoms. When the fertilized cell divides, each of the chromosomes, the maternal and the paternal, likewise divides, lengthwise, into two parts of equal value. The chromosomes move to the poles of the dividing cell, one of each pair to each pole. According to this conception all the cells of a hybrid organism possess in their pure form an equal quantity of both the paternal and the maternal hereditary substance. The result is different in reduction division, which occurs in animal organisms at the time sex cells are formed and in plants before they are formed. The chromosomes do not split lengthwise but form pairs of homologous paternal and maternal chromosomes, then separate and go to the different poles. The cells obtained contain only either the paternal or the maternal chromosome of each pair.

The geneticists are of the opinion that the chromosomes of each parental form in the hybrid cell do not lose their properties, their individuality. They are there in their pure paternal or maternal form. At the reduction division, when from each homologous pair the paternal chromosome goes to one pole of the dividing cell and the maternal chromosome to the other, a pure sex cell (gamete), nonhybrid as regards the properties whose genes are located in the particular chromosome, is obtained.

Thus, in the example we have taken of crossing white-coloured with red-coloured peas half of all sex cells will have a chromosome with a red-colour gene or genes while the other half will possess a chromosome with hereditary particles of white-coloured blossoms. When such hybrid plants are selfed the male sex cells, according to the calculus of probability, may unite with the female sex cells, i.e., the egg cells, in three combinations.

First combination: A male sex cell possessing a red-blossom gene may unite with an egg cell also containing a chromosome with a red-blossom particle (gene). A zygote is obtained whose hereditary substance has only the red-blossom character.

Second combination: A male cell having the hereditary substance of the white-blossom property unites with an egg cell which likewise possesses the white-colour property. A zygote is obtained possessing the hereditary property of white blossoms only.

Third combination: A male sex cell containing the substance which conditions red blossoms unites with egg cells possessing the white-blossom property. A zygote is obtained that has a dual heredity, both red- and white-coloured blossoms. The same happens when male white-blossom cells unite with female red-blossom cells.

In general, self-pollination of the indicated hybrid pea plants produces the following zygotes: 25% with pure red-colour heredity, 25% with pure white-colour heredity, and 50% with dual heredity. With regard to the hereditary blossom-colour characters the following ratios are obtained: 1 red: 2 hybrid: 1 white.

It has long been known that in crossing different forms of peas and many other plants having red and white blossoms the vast majority of hybrids obtained have red blossoms. The same was observed by Gregor Mendel in his pea-crossing experiments. This phenomenon came to be called the dominance of one hereditary property over another, a contrasting property.

On the basis of the reasoning we have set forth the Mendelists arrived at the conclusion that in crossing red-blossom with white-blossom peas there should always be 75% (25% pure + 50% hybrid) red plants and 25% pure white plants in the second hybrid generation. The relation of red to white plants should always be 3:1.

This "pea law," as Michurin aptly calls it, the Mendelists force upon all living nature. The fact of the matter is, however, that it is untrue even for the pea hybrids, including the actual material obtained by Mendel himself in his experiments. Even in Mendel's experiments different offspring of particular hybrid plants varied far beyond the ratio of 3:1. Thus from the offspring of one plant 20 green seeds were obtained for 19 yellow ones and from another plant only 1 green for 30 yellows.

CATEGORIES, GROUPS AND FORMS OF HEREDITY

The various behaviours of hybrids were correctly classified by K. A. Timiryazev. He started out by dividing the phenomena of heredity into two groups: simple and complex heredity.

It is a known fact that self-pollinating plants, as, for instance, wheat or plants propagated by tubers, cuttings, layers, etc., as a rule possess throughout their development the heredity of the maternal form, i.e., the form from which the seeds, cuttings, etc., are taken. This form of inheritance K. A. Timiryazev called *simple.*

On crossing, the heredities of two organisms usually unite. Such heredity is called *complex,* i.e., dual. It in turn may be subdivided into several groups according to the forms in which it manifests itself.

In some animals, for instance, one patch in the pelage resembles the paternal form in colour, another the maternal; or some cells of the epidermis of a leaf resemble the paternal while others the maternal, etc. This heredity is called *mixed* because one part of the organism manifests characters of the one parent and another of the other parent. These parts, or sections, may be of different sizes, from big to microscopically small.

Most frequent are the cases when the hereditary properties of both parents are blended in the offspring (do not manifest themselves in their pure form), when new properties are obtained in the progeny. Such heredity Timiryazev called *blended,* and considered it the most important.

Cases occur when parental characters expressed in opposite ways are not blended in the hybrid offspring. For instance, when crossing a pea variety having green seeds with a yellow-seed variety these characters do not blend in the offspring. Nor is a new or mean property obtained. The property obtained is that of only one of the parents. The property of the other is excluded, so to say. This form of heredity is called *mutually exclusive.*

Two categories may be observed in mutually exclusive heredity.

One of these categories comprises the cases of hybrid organisms that are homogeneous in the first and all subsequent generations. In other words, the hybrid progeny does not become heterogeneous, segregated, in the course of generations; not infrequently the properties of the one parent are completely absorbed by the other. These cases are called *Millardetism,* after the French scientist by that name who studied this category of hybrids quite fully.

The other category of mutually exclusive heredity comprises cases of so-called *Mendelism.*

Timiryazev himself pointed out that those are isolated instances, which occur only under definite conditions and actually were not discovered by Mendel at all. In those cases, beginning usually with the second generation, segregation, diversity, occurs in hybrids, some forms having paternal and others maternal characters.

Today it is clear that all the diverse forms of heredity are possible also in vegetative hybridization.

Vegetative hybrids exhibit mixed heredity when one part of the organism is represented by the properties of one breed, of the one component, and the other part by those of the other breed. Blended and mutually exclusive heredity are also encountered.

In vegetative hybrids we also have either increase in vigour of development or, on the contrary, decrease in viability, i.e., the same as we have in sexual hybridization.

All this does not mean, of course, that there is no difference whatever between vegetative and sexual hybridization. The important thing to emphasize is, however, the fact that vegetative and sexual hybrids manifest common forms of heredity. Neither of these categories of phenomena are separated from each other by an impenetrable wall but represent phenomena of one and the same order.

It has already been pointed out that from the stand they take the Mendelist-Morganists cannot admit the existence of vegetative hybrids. What defied all refutation they classed as incomprehensible, inexplicable phenomena called *chimeras.*

In actual fact the so-called chimeras may be looked upon as manifestations of mixed heredity, one part of the organism exhibiting the properties of the one component and the other part those of the other component. This phenomenon is analogous, for instance, to the case of a piebald or spotted cow one spot of whose hide is coloured like that of the maternal organism and another spot like that of the paternal one. Who would ever think of calling a spotted cow a chimera?

The facts in possession of Soviet agrobiologists are a sufficient basis for evolving a single effective theory of heredity which will fully meet the requirements set forth by K. A. Timiryazev: to serve as "a general working hypothesis, i.e., an instrument for directing the research necessary for the discovery of new facts, new generalizations."

In vegetative hybridization one component is nourished by the other; they enter into metabolic relations with each other. As a result of such interaction between the plants of two breeds a new organism is obtained combining in some measure (depending upon the conditions) the heredity of both components.

The same stand may, in our opinion, be taken with regard to *sexual hybridization,* which is also *a process of metabolic interchange between the fusing components (cells) of the cross.*

If *vegetative* and *sexual hybridization are phenomena of the same order*, it follows that they must have a common basis. This consists in the fact that *both vegetative and sexual hybridization are processes of reciprocal assimilative activity of the components* as a result of which the hybrid product is elaborated.

When looked at in this light Michurin's teaching acquires particular interest. By suitably preparing the organisms and giving them the necessary nutrients Michurin compelled forms which without this were biologically incompatible to crossbreed. He worked out a method of overcoming inability to cross by which each of the components of the cross is fed the products elaborated by the other. This method is a preliminary vegetative approximation. By selecting the conditions of life, the regime of feeding, the sexual process may be changed, directed, thus creating the prerequisites for the absorption of the hereditary properties of the one component by the heredity of the other. Michurin also proved that the hereditary properties of hybrid trees continue to form during the course of their individual lives until the first few years of bearing. The deviation of particular properties of the hybrid toward either component of the cross depends on how the hybrid is nourished.

From this follow the interconnection and mutual transitions that exist between vegetative and sexual hybridization, on the one hand, and between vegetative hybridization and the influence of environmental conditions, on the other.

In this connection the following fact, interesting from the point of view of theory and general biology, should be adduced. It was repeatedly observed several years ago in experiments conducted by Comrade A. A. Avakian at the Odessa Institute of Selection and Genetics and subsequently in the greenhouses of the experimental base of the Lenin Academy of Agricultural Sciences of the U.S.S.R. (Gorki Leninskiye).

The reference is to the following phenomenon. On crossing Hostianum 0237, a winter wheat, with spring wheat 1160 and 1163 (the latter two wheats being full sisters), the seeds obtained were normal. At first sprouts normal in their external appearance developed from them. But when the third leaf appeared the first shrivelled up. As soon as the fourth appeared the second shrivelled up. All the time only the last two leaves remained alive on the plant. In the end the plant perished. Thousands of such plants were under experiment at one time or another and not one of them lived long enough to ear; all died. The Mendelist-Morganists would attribute such a phenomenon to the action of lethal genes. But they would have nothing to offer wherewith to combat this action. They would declare it fatal, irresistible, and would endeavour to show that in such cases there is only one solution: don't take for crossbreeding plant or animal organisms that have lethal genes. Yet a cross of the same combination, Hostianum 0237 and 1160, produced hybrids which vegetated splendidly in these very same greenhouses and yielded viable, non-perishable plants. The point is that one of the components (paternal form 1160) is a spring variety, but for two generations before crossing it was sown in Odessa, not in spring but in the autumn. Then a cross was effected. This proved sufficient to obtain viable offspring. A different rearing of wheat 1160 altered the plant's sex cells; hence the difference in the result of hybridization.

In other experiments made by Comrade Avakian castrated Hostianum 0237 plants were fertilized with a mixture of pollen of the Erythrospermum 1160 variety and of Hostianum 0237, the maternal form. The plants bred from the seeds obtained were of hybrid origin. They were spring plants while the maternal form was a winter plant. But these plants too proved viable, nonperishing. Thus the presence of pollen of the maternal form, in the case in question Hostianum 0237, influenced the result of fertilization with Erythrospermum 1160 pollen. The offspring obtained were not lethal, as is usual in such a cross, but viable.

Michurin, too, pointed out the expedience in certain cases of mixing pollens. By this means he succeeded in crossing species and genera which otherwise could not cross.

All these facts show once more that fertilization, like vegetative hybridization, is a peculiar process of assimilation, of metabolism.

The categories of phenomena connected with cross-pollination also argue in favour of such a conception of the sexual process. As Darwin proved irrefutably, *cross-pollination* is, as a rule, *good for the organism.* Offspring from seeds obtained by means of cross-pollination possess *greater vitality.* According to the explanation given by Darwin, different organisms developing under relatively different conditions build themselves differently from the environing nutrients. Relatively different organisms are obtained and hence also different sex cells. A union of such sex cells differing somewhat in their heredities produces more viable organisms. This is the proposition on which the measure we propose, intravarietal crossing of self-pollinating field crops, rests.

The basis for intravarietal crossbreeding is elective fertilization. It has been pointed out above that each organism, depending upon its breed, its heredity, requires relatively definite conditions for its life and development. An organism usually does not imbibe nutrient elements that are bad for it, if better elements are available. Herein lies the historically evolved adaptability of organisms. Every process in an organism is endowed with relative elective capacity with regard to conditions. In spite of the assertion of the Mendelists to the contrary the sexual process is no exception in this regard.

The study of elective, free fertilization in plants is of great practical and theoretical importance also for an understanding of the laws governing the behaviour of hybrid offspring.

At the Odessa Institute of Selection and Genetics D. A. Dolgushin performed the following experiment: On the plots assigned for the testing of varieties of winter wheat several dozen spikes taken from each of the twenty varieties experimented with in this crop were castrated in 1938. The castrated spikes were given the opportunity of being pollinated by the pollen of any variety. For each castrated flower there was many times more pollen of other varieties than there was of the uncastrated plants of its own type.

In the first generation the seeds obtained from the castrated spikes produced plants whose only point of distinction was somewhat greater vitality, greater vigour than that of the maternal forms sown alongside. All these plants (except a small percentage) showed no morphological differences from the maternal forms, though some of the latter had recessive characters (for instance, awns, white spikes, etc.). In all the twenty varieties the plants of the second generation obtained from the free, elective intervarietal crosses withstood the inclement winter of 1939-40 better than the maternal forms.

The wheat assortment taken included the most frost-resistant variety, Lutescens 0329. According to Morganist conceptions this wheat could not acquire greater hardiness from anywhere on being pollinated by the other varieties inasmuch as all the other varieties undergoing the test were considerably inferior to it with regard to this particular property. It is also of interest to note that in free, elective intervarietal crossbreeding not a single variety of inferior winter-hardiness, like the Kooperatorka, increased its hardiness to any great extent. But in artificial (enforced) crossing of Kooperatorka with more frost-resistant varieties the hybrids, as a rule, considerably surpass the Kooperatorka in hardiness.

This and a number of similar experiments show that frequently in elective, unrestricted fertilization of plants seeds are obtained which produce plants differing little from the maternal type but unfailingly (though not to a great extent) more vital, more resistant to climatic inclemencies.

In our view free, unrestricted, elective fertilization in plants leads, as a rule, to the almost complete absorption of one heredity by another. Much more often than not the maternal heredity absorbs the paternal. We repeatedly observed this phenomenon in experiments with self-pollinating plants, as for instance in the free wind-pollination of castrated wheat with the pollen of various other strains. The same result was obtained in experiments with cross-pollinated plants—rye. I shall refer to an experiment which Comrade Avakian made at the Institute of Selection and Genetics of the Lenin Academy of Agricultural Sciences of the U.S.S.R. Strips 0.5 metres wide and 25 metres long were sown to spring rye, alternating with various winter varieties. At a distance of 3-4 metres from these strips a strip 5 metres wide was sown to Pullman, a variety of winter rye. The plants of all the varieties that were included in the experiment (both winter and spring varieties) flowered simultaneously. Hence the air contained simultaneously a mixture of pollen from all these varieties. On testing the offspring it was found that all winter varieties produced more than 90% winter plants. For example, the Pullman variety produced no more than 1.5% spring plants; all the rest were winter plants, as is usual for this variety. On testing three generations the offspring of the spring variety similarly proved to be almost exclusively spring plants. Only a few solitary plants were of the winter habit. The preservation in the offspring of the maternal plant forms in such experiments can under no circumstances be explained solely by the plants electing the pollen of their own variety. Here undoubtedly there were also such phenomena as the almost complete absorption, assimilation, of one heredity by another, i.e., the maternal heredity absorbed, assimilated the paternal heredity.

From this point of view it is easy to understand the facts observed: prolonged stability of varieties (for instance, annual varieties) of cross-pollinated plants in free nature. They can be freely pollinated by the wind or insects with the pollen of other varieties closely related to them and growing together with them. Nevertheless, year after year, the plants, within the limits of the variety in question, are, as a rule, to outward appearance, of the same form, relatively speaking. At the same time they differ from the other varieties growing together with them. You need only collect seeds of a wild-growing isolated plant of a particular variety (for instance, white poppy), which was surrounded by plants of another variety (red poppy) and sow these seeds, when, as a rule, you obtain, in a considerable majority, plants of the maternal form and only a minority can exhibit the properties of mixed breeds (hybrids). Such experiments with the sowing of seeds of various wild plants were performed by Comrade E. M. Temirazova at the experimental base of the Lenin Academy of Agricultural Sciences, near Moscow.

It is known that in the vast majority of the numerous crosses performed by geneticists and at plant-breeding stations plants with hybrid properties are obtained. In the course of generations these plants show variation (segregate) to a greater or smaller extent. Proceeding from the principles underlying the theory that the hereditary substance is corpuscular (particulate), the Mendelian geneticists assert that the products of any cross between forms that differ from each other are bound, in the course of generations, to result in segregation, i.e., are bound to separate into paternal and maternal characters, and, moreover, in the ratio of $(3:1)^n$. But in actual fact such a separation is not at all necessary, neither in elective nor artificial crossbreeding.

We are in possession of numerous facts which go to show that when castrated flowers are intentionally pollinated with alien pollen, seeds are obtained from which seemingly pure maternal plants grow. The latter, in their turn, in the succeeding generations also produce purely maternal forms. The same results were obtained by Comrade P. N. Yakovlev on a section of the Michurin Central Genetic Pomological Laboratory. The castrated flowers of *Cerasus Besseyi Bail* were pollinated with the pollen of the peach. The stones obtained after sowing produced plants differing in no wise from *Cerasus Besseyi*. It was conceivable that in the case in question the plants were not hybrid because of bad castration. Although *Cerasus Besseyi* cannot be fertilized with its own pollen, the flowers on separate branches of these plants were castrated anew and pollinated a second time with peach pollen. The offspring obtained the second time also could not be distinguished in any way from the maternal form.

Six generations of hybrids were successively castrated and pollinated with peach pollen. Only in the fifth generation two samples with characters of the paternal form—peach—were found among the many plants obtained as a result of planting the stones of such crosses.

Many other cases may be mentioned, for instance, the crossing of currants with gooseberries, apples with pears, etc., where the influence of one of the parents (usually the male) is frequently almost entirely absent in the offspring. To "explain" such cases as instances of parthenogenesis, i.e., the obtaining of seeds without a process of fertilization, is beneath all criticism. The plants referred to will not yield seeds parthenogenetically.

The ineptness of "explaining" cases as parthenogenesis where the heredity type of one of the parents predominates is most patent when the organism obtained in the cross deviates entirely in the direction of the paternal and not the maternal form.

In an experiment conducted by Kh. K. Yenikeyev at the Michurin Central Genetic Pomological Laboratory, a 16-chromosome American plum, Cheresota, was crossed with a 48-chromosome Michurin plum variety, Reine Claude Reforma. The 16-chromosome plum was taken as the maternal form and the 48-chromosome as the paternal. The plant obtained from this cross had the paternal habitus, including the 48 chromosomes, i.e., as many as the paternal plant has.

All these examples clearly attest to the diversity of the biological process of fertilization, which cannot be fitted into the cytogenetic pattern invented by the Morganists.

We have already noted above that fertilization, like every other process in the living organism, is subject to the laws of assimilation and dissimilation. The fusion of two sex cells is a process of assimilation, a process of mutual absorption, as a result of which in place of two sex cells (a male and a female) we obtain a third, a new cell, which we call zygote. The hybrid embryo obtained deviates more or less in the direction of the nature of the sex cell which in its own way assimilates its partner, so to speak, more than the latter assimilates it. If, for instance, both sex cells possess equal power of mutual assimilation (absorption) a zygote (fertilized. cell) is obtained which produces an organism with an approximately equal distribution of maternal and paternal properties and characters. If the power of assimilation of one of the sexual components predominates, the hybrid obtained exhibits greater deviation in the direction of this parent, to the point of the complete absorption of the hereditary properties of the other.

On this basis it becomes possible, when crossing plant forms, to mould the nature of hybrid embryos, causing them to deviate more or less in the direction of the maternal or paternal form. This should be borne in mind when it is necessary to transmit to the hybrid only a certain few properties (such as resistance to adverse climatic conditions). Michurin suggests in his works that in such cases one had better take the pollen from young plants, plants flowering for the first time, whose nature has not yet become settled. Conversely, the flowers of the other component, to which it is desired to add only a few properties of the first parent, must be picked from a strong tree that has already fruited several times, and they must be so placed on the branch that they are assured of the best influx of nutrients. This will create the conditions for the predominance in the offspring of the properties of the one (the desired) variety and the considerable absorption of the properties of the other.

In a number of cases Michurin earnestly advises the choice of forms for crossing that are remote in regard to place (conditions) of origin not only from each other but also from the place (conditions) where the new variety will be formed. This is necessary when a cultivated variety of southern origin yielding good fruits but unable to endure severe winter conditions is taken as one of the parents, and it is desired to obtain a variety that bears good fruits and can resist severe conditions. If such a southern variety is crossed with a frost-resistant local breed, which however yields inferior fruits, the conditions (climate, food, etc.) will promote, enhance the absorbing and assimilating capacity of the local variety's sex cells and a rather undesirable hybrid will be obtained. In this case it is advisable not to take parents (neither the hardy nor the nonhardy) of local origin in order that the external conditions may in equal measure be relatively unsuitable—be averse to the development of the properties of both components in the formation of the embryo. From such hybrid seeds it is easier to grow varieties that yield good-quality fruits and can withstand unfavourable conditions, provided the plants obtained from these seeds are skilfully trained.

The sexual process of plants can be regulated It is possible to obtain hybrids which obviously deviate in some measure or other in the direction of either parent. A hybrid generation can be bred that varies in only a minor degree. Not infrequently hybrids are produced which from the first generation are practically stable and transmit this property through their seeds from generation to generation.

It now becomes clear in what cases spatial or other isolation of crops of cross-pollinating plants from pollination by other varieties is absolutely necessary and in what cases not. In all cases where the biological usefulness of a plant property conflicts with its economic usefulness, isolation of the seed plants of the variety in question during flowering from foreign pollen is essential. This is of particular importance, for instance, in the seed growing of garden and technical crops. Spatial isolation during flowering is an absolute requisite for plants like cabbage, carrots, red beets, sugar beets, hemp and many others. On the other hand, in cases where the biological usefulness of a character or property coincides with its economic usefulness spatial isolation is not only not useful but frequently even harmful. For example, when the hardiness of a particular variety of rye to severe wintering conditions has to be increased, growing such rye near crops of other varieties will certainly be useful. On this account it will be advisable also in the case of self-pollinators of field cultures, whose hardiness and resistance to climatic inclemencies frequently have to be increased, to castrate part of the plants when sowing these varieties and give them the opportunity of being fertilized electively by the pollen of other varieties sown alongside.

By selecting the conditions which most effectively "humour" the plant (elective fertilization, superior agrotechnique, etc.) the breed properties of plants can slowly, gradually but continually be improved, perfected.

By selecting the conditions which force a plant to abandon the fixed trend of its adaptability and thus destabilizing, abolishing the conservatism of its heredity (either by sharply changing the conditions of cultivation or by enforced fertilization, especially in distant crosses) it is possible in subsequent generations, by a proper choice of the conditions of training, rapidly to create new requirements of the plant, to create new breeds and varieties differing radically from the initial ones.

Regulation of environmental conditions, the conditions under which plant organisms live, makes possible directed change, the creation of varieties possessing the heredity we desire. *Heredity is the concentrate, as it were, of the environmental conditions assimilated by plant organisms in a series of preceding generations.*

By means of skilful hybridization, by the method of sexual conjugation of breeds, it is possible at once to unite in one organism that which has been concentrated, assimilated and fixed in its passage from nonliving to living material by many generations. But no hybridization will produce the desired results unless the conditions are created which will promote the development of the characters which we want the newly-bred or improved variety to inherit.

It must be remembered that nonliving nature is the prime source of living nature. The living body builds itself from the environmental conditions and thereby changes itself.