THE "PRESENCE AND ABSENCE" HYPOTHESIS[1]

DR. GEORGE HARRISON SHULL

STATION FOR EXPERIMENTAL EVOLUTION, CARNEGIE INSTITUTION OF WASHINGTON

IN Mendel's[2] discussion of the behavior of characteristics in the offspring of splitting hybrids, the phenomena of segregation are described in terms of pairs of antagonistic characters. He assumed that these are represented by pairs of internal units, one member of each such pair coming from one parent, the other from the other parent. This idea of pairs of characters in Mendelian hybrids has been generally entertained until somewhat recently, and is still perhaps not uncommonly held. De Vries[3] made use of this conception in stating what he thought to be a fundamental distinction between species and varieties, assuming that the differentiating features of varieties are represented by units which are homologous with corresponding units of the species from which such varieties sprang, and which are paired with those units on crossing, while different species lack such homology and pairing of determiners.

About six years ago in a paper on Mirabilis crosses, Correns[4] stated the members of several Mendelian "pairs of characters," as the presence and absence of *single* characters. Cuénot[5] in a paper doubtless written simul-

[1] Read before the Botanical Society of America, at Baltimore, December 31, 1908.

[2] Mendel, J. G. "Versuche über Pflanzen-Hybriden." *Verhandlung des Naturforscher-Vereines.* Brünn IV. 47 pp., 1866.

[3] De Vries, H. "Species and Varieties: Their Origin by Mutation," pp. 847, 1904. See p. 251 *et seq.*

[4] Correns, C. "Weitere Beiträge zur Kenntnis der dominierenden Merkmale und der Mosaikbildung der Bastarde." *Ber. d. deutsch. Bot. Ges.* **21**: 195–201, Ap. 23, 1903.

[5] Cuénot, L. "L'hérédité de la pigmentation chez les souris" (2me note). *Arch. de Zool. éxpér. et gén.*, 1 (4th S.): 33–41, 1903.

taneously with Correns's paper, but published several months later, used the same expression,[6] and most recent writers on Mendelian inheritance have adopted the method of presenting the characters in the terms of presence and absence.[7]

But while this change of usage has gradually taken place, little attention has been given to the real significance of the newer method of statement, except by Hurst,[8] who gives a good general discussion of the presence and absence hypothesis in a paper read before the Third International Conference of Genetics two years ago.

Hurst showed that of 44 Mendelian characteristics of various plants and animals studied by him, 41, or more than 93 per cent., can be appropriately described in terms of presence and absence. As one reviews these various characteristics, he can not avoid the feeling that in a number of cases the presence and absence could be read quite as well backward as forward, and it will doubtless be impossible in many cases to decide which is the positive character and which its absence. Thus in the contrast between a yellow and a green pea, the yellow is described

[6] Cuénot has not followed up the idea however in the development of a consistent usage, but continues to treat the supposedly antagonistic characters as if they are alike positive and represented by antagonistic internal units which he conceives to be the chromosomes. The idea that the chromosomes are the determiners of the Mendelian unit-characters has been also advocated by Spillman, but the latter appears to accept the correctness of the presence and absence hypothesis.

[7] Davenport considers "presence and absence" a relatively rare phenomenon. He says: "I think it is clear that dominance in heredity appears when a stronger determiner meets a weaker determiner in the germ. The extreme case is that in which the strong determiner meets a determiner so weak as to be practically absent as when a red flower is crossed with a white." (Davenport, C. B. "Determination of Dominance in Mendelian Inheritance." *Proc. Amer. Phil. Soc.*, 47: 59–63, 1908. See p. 63.) In papers which have come to hand since my paper was read at Baltimore, Bateson and his co-workers, and Castle have, on the other hand, declared unequivocally for the presence and absence hypothesis, as having general validity. See Bateson, Saunders and Punnett, "Experimental Studies in the Physiology of Heredity." Reports to the Evolution Committee of the Royal Society, IV, pp. 40, 1908, see p. 2, and Castle, W. E., "A Mendelian View of Sex-heredity," *Science*, N. S., 29: 395–400, March 5, 1909.

[8] Hurst, C. C. "Mendelian Characters in Plants and Animals." Report of the Third International Conference on Genetics, pp. 114–128, 1906.

as present in the yellow pea and absent in the green pea. What is to hinder us from describing the green as present in the green pea and absent in the yellow one? Similarly in the contrast between tall and dwarf, one could perhaps say "presence and absence of dwarfness on a tall basis" as appropriately as "presence and absence of tallness on a dwarf basis," and there seems no sufficient reason why the palm type of leaf in Primula should not just as well be considered a shortened fern type, as the fern an elongated palm type, or that the thrum is a shortened pin-eye quite as well as that the pin-eye is an elongated thrum. But notwithstanding such difficulties as these, there can be no question that most of the phenomena of Mendelian inheritance are more simply stated in terms of presence and absence than in any other way.

It has appeared to several writers as a difficulty for this hypothesis that in a number of cases what appears to be the absence of a character is dominant over its presence. There are a number of noteworthy cases of this kind. Thus, in cattle the hornless condition is dominant over horns; in most breeds of poultry white plumage dominates over colors and white legs over yellow legs; in snails unbanded shells dominate over banded, and less banded over more banded; in wheat, smooth heads dominate over bearded; in flowers having a yellow plastid color, white is dominant over yellow; in canary birds the presence of a mottled pattern is dominated by its absence, though in most cases color patterns are dominant over their absence. Thus in the mottled varieties of beans, for instance, the mottling factor is dominant over its absence, and in rabbits, the English-marked, Dutch-marked, tan-marked, tortoise-yellow, and agouti patterns are in each case dominant over their absence.

At several places Hurst states (*loc. cit.*) that the assumption that a certain character is the presence-character would "imply the dominance of that character," though in eight instances among the 44 he cites, he definitely places the absence dominant over presence. In

speaking of thrum and pin-eye Primulas (p. 122) he says:

> If we regard it as presence and absence of pin on a thrum basis this would imply dominance of pin over thrum in the zygote.

Again regarding the dominance of short hair over Angora in rabbits (p. 125) he says:

> If on the other hand we regard it as presence and absence of Angora on a short basis, this would imply dominance of Angora over short in the zygote.

Both Bateson and Davenport appear to have tacitly agreed that the dominance of absence over presence is a difficulty for the "presence and absence" hypothesis, for both have taken occasion to explain that what appears to be the absence of a character may really be the presence of a positive inhibiting factor. Indeed, Davenport[9] has taken the position that the positiveness of a character determines its dominance, and, therefore, all cases in which the absence of an external character dominates its presence must be explained by the existence of a positive factor in whose presence the given external character can not be produced. Thus, he says:

> A progressive variation, one which means a further stage in ontogeny . . . will be dominant; a variation that is due to abbreviation of the ontogenetic process, which depends on something having dropped out, will be recessive.

While I recognize the probability that there are positive inhibiting factors, as well as factors which produce specific structural and color characters, I think it can be shown that such an assumption is not necessary for the explanation of the dominance of the absence of a character over its presence. I will assume for the sake of the discussion that the presence and absence hypothesis is correct, and that the absence is real, having no internal unit to represent it. This assumption seems to me, as it did to Hurst, to be simpler and more practical than the alternative idea that the internal units are paired in the heterozygote, having a representative for absence as well as one for presence. I believe there is no fact on record[10]

[9] Davenport, C. B. Report of the Third International Conference on Genetics, p. 139, 1906.

[10] Except perhaps so-called "spurious allelomorphism."

which can not be as well explained on the basis of a single unit, as a pair of units.

On this basis the fundamental difference between the three classes of individuals produced by self-fertilization of a heterozygote may be simply stated thus: There are two classes of homozygotes, usually designated *DD* and *RR*, and the heterozygote, usually referred to as *DR*. The difference between the two kinds of homozygotes with respect to any unit-character is, that one—usually the *DD*—has one pair of allelomorphs or "genes"[11] in addition to those possessed by the other kind of homozygote—usually the *RR*. As the two kinds of homozygotes are often not appropriately called dominant and recessive, I will call the one which has the added pair of genes (*i. e.*, the one which has $2n+2$ genes) the "positive" homozygote, and the one which lacks them (*i. e.*, the one with only $2n$ genes) the "negative" homozygote. If we designate collectively the common features of two parents which differ from each other in a single unit-character by the letters *BB*, and the differentiating genes by the letter *A* repeated as often as the gene is repeated in each nucleus of the soma or sporophyte, the positive homozygote will have the composition *AABB*, the negative homozygote will be simply *BB*, and the heterozygote will be *ABB;* and whatever differences are observable in these three classes of individuals must be due obviously to the presence of none, one, or two "*A*" genes in each nucleus and to the reactions of these with the underlying factors which have been here collectively represented by "*BB*."

In order to see the bearing of these assumptions upon questions of dominance we must consider briefly the nature of the unit-characters. Regarding the nature of the genes themselves—the primary character-producing

[11] This word is proposed by Dr. Johannsen as a substitute for words such as pangenes, ids, allelomorphs, etc., which have been used to denote an internal something or condition upon whose presence an elementary morphological or physiological characteristic depends. The word "gene" has the advantage that it does not assume by its form or derivation any hypothesis as to the ultimate character, origin or behavior of the determining factor.

units—I have nothing to suggest, for to that question I am, like Professor Bateson,[12] inclined "to hold my fancy on a tight rein;" but there can be no doubt that the *visible* Mendelian characters are always secondary, and but little doubt that they are all dependent at some stage of analysis upon chemical relations.

This is too obvious to need discussion in the case of color-characters, and in those structural characters which involve only some by-product of the metabolism of the cells as, for instance, the starchy or sugary character of the endosperm in maize. It requires perhaps a more daring flight at present to assert that such structural characters as hairiness, branching, lobation and serration of leaves, production of horns, extra toes, different forms of comb, etc., which involve the number, direction and succession of cell-divisions, depend likewise upon the intimate chemical nature of the protoplasts; but even if it could be shown that *physical* properties of the protoplasm are to a certain degree determining conditions of cell-division, the resulting structures could hardly conceivably be permanent hereditary features, unless these physical properties are dependent at last upon the chemical composition of the protoplasm.

Having arrived at the conclusion that all the Mendelian characters are dependent upon chemical relations, we may return to the question of dominance, and the relation between the two kinds of homozygotes and the heterozygote, and see to what extent the known facts may be interpreted in terms of chemical experience.

A fundamental principle in this connection is the law that the extent of a reaction between two chemicals is determined by the amount of that reagent which is present in less relative quantity, and not by the one which is present in excess. When the positive homozygote, *AABB,* and the heterozygote, *ABB,* are alike, *i. e.,* when there is complete dominance of presence over absence, it

[12] Bateson, W. The Methods and Scope of Genetics, 49 pp., Cambridge, The University Press, 1908. See p. 12.

may mean that already the presence of the one unit *A* of the heterozygote is sufficient to result in the maximum reaction, in which case the doubled factor *AA* of the positive homozygote can do no more. When, on the other hand, one unit *A* is not sufficient to produce a maximum reaction with the other factors present, the *AA* of the homozygote produces the corresponding character in greater intensity, and the heterozygote will be intermediate between the two homozygous parents. Both of these conditions are frequently realized.

The case I have wished to deal with specifically is that in which the heterozygote—the *ABB* individual—does not differ in external aspect from the *negative* homozygote, *BB*, so that the ratio becomes 1:3 instead of 3:1, this is the situation in which the absence of a character is dominant over its presence. In such a case the character determined by *A* is latent in the heterozygote. To show that this situation is possible it need only be pointed out that in a number of familiar instances a precipitate is formed or some other visible reaction takes place only in the presence of a certain excess of one of the reagents. It is perfectly clear that in any such case, one may add nearly enough of the reagent which is required to be in excess, and no apparent reaction will take place, but if the quantity of this reagent be doubled the characteristic reaction will occur. Now this is just what I conceive may take place in certain crosses. In the heterozygote where the chemical unit *A* (of whatever nature) occurs but once in each nucleus, no reaction becomes apparent, but in the pure-bred forms bearing the unit *A* in double quantity, *i. e., AA,* the specific character (or reaction) produced by this unit appears. The heterozygotes will then be indistinguishable from the negative homozygote, and in the offspring of two heterozygotes bred together there will be among every four individuals on the average three which have the character absent and one which has it present, or in other words "absence will be dominant over presence."

Very neat laboratory experiments can be arranged to illustrate this behavior, with any reaction in which a certain excess of one of the reagents is required, and while these reactions will probably be in most cases of much greater simplicity than those presented by the interaction of the hereditary units, and they can, therefore, be considered only as presenting analogies, I am convinced that such analogies are not unfair ones.

It is especially easy to arrange an experiment showing such a result in the case of certain organic substances known as indicators, as litmus and phenolphthalein, for here one needs to assume only that the single, unpaired unit in the heterozygote produces such a quantity of acid or alkali as will not quite change the character of the cell-sap of the negative homozygote with respect to acidity or alkalinity. Thus if I make an alkaline solution of litmus and add to it as the product of one assumed unit, *A*, such a quantity of any acid as leaves the solution still slightly alkaline, I may allow this to represent the heterozygote. Then the homozygote possessing the acid-producing unit *A* will have it in double quantity or intensity. When I add this second portion of acid to the solution it is instantly changed from alkaline to acid, as is indicated by a change from blue to red color. The negative homozygote lacking the acid-producing unit and the two heterozygotes are alike blue, while the individual which is pure with respect to this unit whose specific external manifestation is the production of a red color, alone possesses that character, and this results in a realization of the ratio, 3 absences to 1 presence, or the dominance of absence over presence. This example has the advantage of being conceivably duplicated in the case of many vegetable color-characters, for the very widely distributed anthocyan which gives the red and blue colors is an indicator similar to litmus, and could have been used in this experiment instead of litmus.

Whether the situation here outlined is actually attained in the case of red and blue flowers in nature can not per-

haps be demonstrated. It is the general experience that blueness is dominant over its absence, but this is just the result I have pictured here as a case in which absence of redness or of acidity is dominant over its presence. I know of no way of determining whether red flowers are blue flowers with an added factor for acidity, or whether blue flowers are red with an added factor for alkalinity, and, indeed, it is conceivable that both of these situations may be presented in different species. However, my purpose is attained if I have shown that there is no greater theoretical difficulty involved in the dominance of absence over presence than in the dominance of presence over absence, and that the assumption that any given character is due to the presence of an added internal unit does not "imply the dominance" of that character.

The non-appearance of an externally visible character in the heterozygote, although the corresponding internal unit is present, as must always be the case when real absence is dominant over presence, plainly presents a kind of latency somewhat different from the four types recognized by me[13] in a recent article in the AMERICAN NATURALIST. For the sake of uniformity with the terminology there adopted I may call this new kind of invisibility "*latency due to heterozygosis.*" Like all the other types of latency except that due to fluctuation, the latency resulting from heterozygosis produces no deviation from definite characteristic ratios.

I recall at present only one case in which we can certainly identify latency due to heterozygosis, for the reason that, just as we have seen above in regard to blue and red flowers, it may be quite impossible in any particular instance to decide which is the positive character and which its absence. In a particularly interesting cross between a yellow and a reddish snail, Lang[14] has found

[13] Shull, G. H. "A New Mendelian Ratio and Several Types of Latency," AMERICAN NATURALIST, 42: 433–451, July, 1908.

[14] Lang, A. Ueber die Bastarde von Helix hortensis Müller und Helix nemoralis L. Eine Untersuchung zur experimentellen Vererbungslehre. Jena: G. Fischer. 1908.

that the heterozygotes are yellow when young and red when they grow older. In this case the appearance of yellow in the young stage leaves no doubt that this is the fundamental color upon which the red is superposed. The pure bred red snail—the positive homozygote—is red from its earliest stages. This latency of the red character in the young heterozygotes produces a dominance of the absence of red over its presence in the early stages of development, and if the snails are classified at this time, the F_2 is found to consist of 3 yellows to 1 red. Later in life the heterozygotes become red and the census shows 3 reds to 1 yellow.

The rather frequent occurrence of heterozygotes lacking the usually dominant character may be quite appropriately said to present cases of latency due to the combination of fluctuation and heterozygosis.

Summary

The "presence and absence" hypothesis assumes that what appears to be a pair of characters in Mendelian inheritance is really the presence and absence of a single character. This hypothesis has now won the support of most of the leading experimental students of heredity. The fact that the absence of certain characters dominates over their presence has appeared to some to be a difficulty. This paper shows that no such difficulty is involved and simple chemical experiments are cited which, if duplicated among plants and animals, as they no doubt are, would give the dominance of absence over presence, without recourse to "inhibiting factors."

When absence dominates over presence the positive character is latent in the heterozygote. Such cases may be said to show *latency due to heterozygosis.* This condition is exemplified by some of Lang's snail crosses. The same phenomenon is involved in many cases of failure of dominance in heterozygotes.

Station for Experimental Evolution,
Cold Spring Harbor, L. I.
December, 1908.