NOTES AND LITERATURE

HEREDITY

Spurious Allelomorphism: Results of Some Recent Investigations.—The original conception of a Mendelian character pair was that of two antagonistic characters, one of which dominates the other in such a way as to prevent the development of the other in individuals inheriting both characters, the *anlagen* of the two being so related to each other in the mechanism of the cell that the pair separates in the reduction division. This conception has recently been modified by leading Mendelian investigators so that now a Mendelian pair is looked upon as presence and absence of a particular Mendelian character, presence being dominant to absence. There are some apparent exceptions to this rule of dominance, but they are probably only apparent.

Some recent investigations indicate that we must still further modify our conception of pairs of hereditary characters. Bateson was the first to call attention to a case[1] which he later[2] terms spurious allelomorphism. It is a case in which two dominant characters behave in transmission as a character pair. *i. e.,* they are alternative in transmission—they can not be transmitted by the same parent to a single offspring. Perhaps, at the outset, we should broaden this conception a little so as to provide for the pairing of any two physiologically unrelated characters, whether dominant or recessive. A suitable term to designate such pairs is needed. The term *appomorphs* would answer the purpose very well were it not for the more or less arbitrary rule of philological *fashion* that hybrid words are not permitted. The first two syllables of this word are Latin, and contain the idea of apposition—the two characters are *apposed* in the reduction division. The last syllable is Greek. Possibly a hybrid word may be permitted in dealing with hybrids unless a good "pure-bred" word can be found.

The first case to which Bateson called attention was that of the erect standard and blue flower color in sweet peas.[3] These two

[1] *Science,* November 15, 1907.
[2] *Science,* May 15, 1908.
[3] *Science,* November 17, 1907.

characters form an alternative pair in the plants with which he dealt. Bateson calls attention to the interesting fact that both are characters of the wild sweet pea. Assuming that in the wild species these characters are transmitted together, we must further assume complete correlation between them; the complex pair thus being blue flowers and erect standard paired with blue flowers and erect standard. The cultivated forms have thus arisen by the loss of erect standard in one member and of the blue factor in the other, leaving the pair consisting of blue flowers on the one side and erect standard on the other. This may be clearer if we express it in formulæ. Let B = the blue flower factor, and E the erect standard. In the wild pea we have BE — BE as the pair of correlated characters, while Be — bE is the form assumed by this pair in the cultivated forms.

The next case of spurious allellomorphism was also found by Bateson,[4] while studying some extraordinary results obtained by Doncaster and Raynor in breeding certain moths (*Abraxas grossulariata* and its var. *lacticolor*). If we let G stand for the character in which the species differs from the variety, and L for the corresponding character in the variety, the results to be explained may be stated as follows:

1. ♀L × ♂G gives only ♀G and ♂G (No L).
2. ♀G × ♂L gives only ♀L and ♂G.

Furthermore, when the male used is a product of either of the above crosses, then

3. ♀G × ♂G gives ♀L, ♀G, ♂G, but no ♂L.
4. ♀L × ♂G gives ♀L, ♀G, ♂L and ♂G.

The following explanation of these phenomena is not given in Bateson's terminology, which seems to the writer to be needlessly involved, but it is based on Bateson's explanation.

Let F = the female character and f its absence.

Let G = *grossulariata* character and g its absence and assume that F and G are allelomorphic to each other.

Result No. 1 above now becomes Fg × GG = FG + GG, or female G and male G.

No. 2 becomes FG × gg = Fg + Gg, or female L and (heterozygote) male G.

No. 3. FG × Gg = FG + Fg + GG + Gg, or female G, female L, and male G.

No. 4. Fg × Gg = FG + Fg + Gg + gg, or female G, female L, male G, and male L.

[4] *Science*, May 15, 1908.

It is noteworthy that the male lacticolors produced in these experiments were the first known, all known specimens of the variety having been females. The reason for this is not far to seek. Male L's occur only when female L's mate with hetero-zygote males. The latter arise (from G parents) only in those matings which produce female L's (see mating No. 4 above). Heterozygote males are therefore as rare as female L's. If $1/n$ of the female population is L, then $1/n$ of the male population is heterozygote. The chance that these two shall mate is therefore $1/n \times 1/n = 1/n^2$. Hence, if only 1 female in 1,000 is L, only one male in 1,000,000 is L, which probably accounts for their having escaped the collector.

In the above case the female sex character seems to be paired with G. This is indeed a highly interesting fact, if true, and the results of Doncaster and Raynor leave little room for doubt that it is true. It now seems probable that sex is a property of a particular chromosome.[5] If this is the case, then the G character should also belong to a particular chromosome.

Bateson[5] also calls attention to what appears to be a similar case of allelomorphism between the sex character and a color element, in the case of black pigmentation of silky fowls, when crossed with Brown Leghorns or other fowls with light shanks.

I desire now to call attention to a similar case that has come under my own observation. It is well known to breeders of Barred Plymouth Rock fowls that an occasional black bird crops out in this breed, and that these blacks are invariably females. Mr. J. F. Spilman, of Wentworth, Mo., tells me that he once crossed some Black Langshan males on his Barred Rock females with the result that in the progeny all the females were black and all the males barred. I have also seen, at the Mississippi Ex-periment Station, some crosses between Barred Rocks and Indian Games in which part of the progeny was black, the remainder being barred. Unfortunately, in this case, no observations were made as to a possible relation between color and sex. While the data just given are insufficient to establish beyond question the following explanation, the explanation is given in the hope that it may stimulate investigation on this point. Let us suppose that the female sex character (F) is paired with the barring element (B). Let f = absence of F and b = absence of B. Then a cross between a female Barred Rock and a male Black

[5] See remarks by Bateson, l. c.

Langshan becomes FB × bb = Fb + Bb, or black (non-barred) females and barred males, as in J. F. Spilman's experiment. It may be plainer to some if we write the above Fb — Bf × fb — fb = Fb — fb + fB — fb.

Here F is correlated with b, and f with B; that is, in terms of the chromosome theory, the chromosome which carries F does not carry B, and *vice versa*, though these two chromosomes unite in synapsis to form a bivalent chromosome.

The origin of black females from barred parents is, under our theory, the result of mating a barred female with a heterozygote male; thus: FB × Bb = FB + *Fb* + BB + Bb.

This mating gives half of the females black, the other half and all the males being barred.

But if we mate a homozygote male barred bird with a non-barred female (carrying black color of course), we get BB × Fb = FB + Bb, both sexes being barred.

The result of this last mating has not yet been demonstrated. The same is true of the next mating, between a heterozygote barred male and a non-barred female, which should give Bb × Fb = FB + Bb + *Fb* + *bb;* that is, half of each sex black.

Some similar relation undoubtedly exists between a color element and the sex element both in geese and in ducks, for there are certain breeds of geese in which the males are all white and the females all colored; while in ducks certain breed crosses give the males all of one color and the females all of another.

Two very interesting cases of allelomorphism between two physiologically unrelated characters are found in the recently published work of Noorduijn on "Inheritance in Canary Birds."[6] The data given are not quite full enough to permit their complete elucidation, but they indicate clearly a pairing of the sex element (female) with yellow coat color, and also with a factor of the compound (from the Mendelian standpoint) eye color. There are three principal colors in canaries, namely, yellow, cinnamon (brown), and green. Since mating yellow and cinnamon always gives green birds (usually variegated, but part of the body green) we may infer that the green color arises from the combination of yellow and cinnamon, or of characters correlated with these. Noorduijn states that there are three pigments in the feathers of green canaries, namely, yellow, brown and black.

[6] C. L. W. Noorduijn, in *Arch. f. Rass-. u. Gesell.-Biol.,* April, 1908, p. 162 et seq.

In a letter to the writer he states that in a solution of potash the yellow pigment disappears very quickly, the brown somewhat slowly, while the black disappears only after a much longer interval. My interpretation of Noorduijn's results is that yellow and cinnamon color characters in canaries are probably simple Mendelian characters (unit characters), while black is due to the meeting of two Mendelian factors one of which is correlated with cinnamon and the other with yellow. The case is probably more complex than here indicated, for some of the results indicate the presence of factors in addition to those here assumd. The principal results can now be explained by assuming that C (cinnamon or brown) and Y (yellow) are independent of each other, and that the female sex element (F) is paired with Y. Noorduijn's four cases are:

I. C♂ × G (green or green variegated) females gives G♂ and C♀. This cross sometimes gives G♀'s but never C♂.

II. G♂ × C♀ gives both sexes G.

III. C♂ × Y♀ gives G♂ and C♀. Also sometimes G♀ but never C♂.

IV. Y♂ × C♀ gives both sexes G.

In the above no account is taken of variegation, which Davenport has shown to be itself a Mendelian character.[7] The Mendelian formulæ for Noorduijn's four cases now become (remembering that when C and Y occur in the same bird the color is green or green variegated).

I. CCyy × CCFy = CCFy + CCYy.
              C♀   G♂

II. CCYY × CCFy = CCFY + CCYy.
              G♀   G♂

III. CCyy × ccFY = CcFy + CcYy.
              C♀   G♂

IV. ccYY × CCFy = CcFY + CcYy.
              G♀   G♂.

This does not account for occasional green females from crosses I and III, from which fact additional factors not here considered are indicated; but the formulæ indicate quite clearly that the sex element is paired with yellow coat color, or possibly with one factor of this color. This assumption is confirmed by Noorduijn's statement that yellow males tend to impress their color

[7] C. B. Davenport. Inheritance in Canaries. Carnegie Institution, 1908.

more than yellow females. According to our assumption this should be the case, since yellow males transmit yellow to all off-spring, while yellow females transmit yellow only to their male offspring.

That one factor of the eye color in canaries is allelomorphic to the female sex element is also clearly indicated by Noorduijn's results. He gives only a meager portion of his experimental results on this point, so that the phenomena can not be explained here. There is enough to indicate that the case involves at least three independent Mendelian factors, one of which is correlated with yellow coat color, and hence allelomorphic to the sex element.

<div align="right">W. J. Spillman.</div>

HUMAN ANATOMY

Sexual and Family Variation in Centers of Ossification.—Dr. J. W. Pryor, professor of anatomy and physiology at the State University, Lexington, Kentucky, for several years has been carrying on an investigation of the ossification of the bones of the human carpus, by means of X-ray photographs. He has made a study of over 550 hands, of which 266 were those of girls and 288 those of boys. In numerous instances he has examined the hands of the same individual at different periods, and has also made a study of the ossification of the bones in children of one family compared with those of other families. In a recent article in the *Bulletin of the State University,* Lexington, Kentucky, April, 1908, he has summed up some of the conclusions arrived at in previous publications, and has brought forth new material in confirmation of his more important generalizations. He finds centers of ossification appear earlier and develop faster in the bones of the female than in those of the male, and that this difference is measurable in infancy by days, in early child-hood by months, and later by years. The bones of the first child will, as a rule, ossify sooner than those of subsequent children of the same parents. There is considerable difference in the children of different families in the period when centers of ossification appear, but within a given family there is, as a rule, considerable similarity. Variation in the ossification of bones is an heritable trait. The studies of Professor Pryor enable him to give a more accurate table than has hitherto existed of the period when the centers of ossification appear in the carpal bones. The