The results show that not only do incubators hatch a smaller percentage of chicks from a given number of eggs than the hens, they also show that the artificial method is productive of "infertility" if all eggs that are tested out as infertile are to be so rated. This of course, is not the case because many of the tested out eggs have been fertile, but during the process of incubation the embryo has died in the shell.

The serious problem, however, is probably not how to hatch a certain percentage of the eggs set, but how to hatch the greatest number of chicks of good vitality. A study of the vitality of the chicks was made. Chicks hatched under hens weighed when hatched heavier than chicks hatched in incubators. The death rate of hen-hatched chicks brooded in artificial brooders was 10.8 per cent and of incubator chicks 33.5 per cent. The death rate in hen-hatched chicks brooded by hens was 2.2 per cent and of incubator chicks 49.2 per cent in four weeks. Other tests showed a mortality of 46.5 per cent of incubator chicks brooded by hens and 58.4 brooded by brooders. In this way the low vitality was traced directly to the incubators as the cause, and the various theories that the mortality in brooder chicks was due to improper brooding or feeding of the chicks or to lack of vigor in the parent stock were shown to be without foundation.

In the nine years' breeding work at the Maine station artificial methods were used in hatching and brooding the chicks, and while we are guessing at the failure to secure a higher egg yield in those experiments I venture the guess that the failure was due to a gradual lowering of vitality in the stock by artificial incubation.

It seems especially desirable that any poultry breeding work looking to increased egg production should not be dependent upon the success or failure of artificial methods of hatching.

THE FACTOR HYPOTHESIS IN ITS RELATION TO PLUMAGE COLOR.

BY C. B. DAVENPORT, *Cold Spring Harbor, N. Y.*

An egg that is one millimeter in diameter contains all the materials necessary to determine the different characteristics of an ox. And not an ox, merely, but an ox of particular breed and strain, with peculiarities of proportions, of head and horns, of length, quality and color of the hairs. When we contemplate such facts we are forced to conclude that there are, in the egg, representatives of each part and that these must

be stuffs of various specific kinds. Nowhere is the truth of this conclusion more strikingly illustrated than in the pigment of the fowl's plumage.

There are in poultry three fundamental colors: white, black and golden. These colors are not, however, simple and elementary. Thus of *white*, there are two kinds. One white is typical of certain oriental fowl—Cochins and silkies: the other of western fowl—the white Leghorn and its derivatives. The first is an albinic white, due to the absence of pigment: the second is a gray-white, probably due to an interference with pigment production or the destruction of pigment as fast as formed. In the first type some element necessary to form pigment is lacking; in the second the necessary elements are there but there is an additional something that destroys them. So with *black*, there are at least two conditions in which it occurs. There is a fundamental black such as that of the tail of the male game or brown Leghorn and there is a superficial black such as covers over the red wing-bars and hackles, making uniform iridescent-black plumage like that of the Minorca, Spanish, black game and Sumatra. Finally, the *golden* color occurs as a lighter buff and as a darker red—as on the wing bar. Now there can be no doubt that each fundamental kind of pigment is due to a distinct chemical composition or condition and the question of the behavior of pigment color in heredity is a chemical question.

If a colorless fluid extract of the ink gland of the squid be added to a colorless solution of tyrosin, the combination becomes at first light brown and gradually black. This black color is something new, not seen in either of the two substances brought together; but it is due to the *combination* of the two colorless factors. One can not say the black character is latent in either substance nor would it help us to understand the result if we should say it is a reversion to an ancestral condition of the tyrosin. Refuge in such an "explanation" would not be permitted to a chemist. Similarly if one mates a black Minorca and a white silky the black cockerels that are produced gain much red, like that of the Brown Leghorn cock. Whence comes this red? The biologist says "reversion" and formerly this word sufficed as a philosophical explanation; but biology has now reached a stage of development where so mystical an explanation will no longer satisfy. We now have good experimental evidence that the red color of the male hybrid results from the interaction of color-forming enzymes and colorless pigment granules. Two such substances that interact to produce something different from either are called, nowadays, *factors*.

The factor hypothesis is the key to many riddles in breeding and to illustrate its application I propose to cite an example from my own experience. Thus, in the instance cited above, where a black Minorca is crossed with a white silky, we are led from this and other evidence to conclude that the silky really contains a factor that we may call the Jungle Fowl coloration and designate by J. But the silky lacks the color producing enzyme and the ability to form the superficial black pigment that obscures red. These defects are symbolized by the small letters *c* and *n*. The Minorca, on the other hand, possesses the color enzyme, C, and the Jungle Fowl coloration, J, but this is obscured by the superficial black, N. The combination of *cJn* × *CJN* gives *CcJJNn*—a bird with color, with the Jungle Fowl pattern and with heterozygous black, which means that the superficial black is diluted and hence not able to obscure completely the red of the Jungle pattern. Consequently the male hybrid shows traces of the Jungle, or game, red.

The hybrid birds produce four kinds of gametes as follows: *CJN*, *CJn*, *cJN*, *cJn*, and, when mated with its like: *CJN*, *CJn*, *cJN*, *cJn*, 16 kinds of combinations (zygotes) are possible.

ZYGOTE.	SOMA.	ZYGOTE.	SOMA.	LEGEND.
$C_2J_2N_2$	N'	$C_2J_2N_2$	N'	C, presence of color enzyme
C_2J_2Nn	N'(+R)	CcJ_2Nn	N'(+R)	c, absence of color enzyme
CcJ_2N_2	N'	$c_2J_2N_2$	W	J, Jungle fowl coloration
CcJ_2Nn	N'(+R)	c_2J_2Nn	W	N, presence of black factor
C_2J_2Nn	N'(+R)	CcJ_2Nn	N'(+R)	n, absence of black factor
$C_2J_2n_2$	J'	CcJ_2n_2	J'	N' black in plumage coloration
CcJ_2Nn	N'(+R)	C_2J_2Nn	W	(+R) a little red in plumage
CcJ_2n_2	J'	$c_2J_2n_2$	W	W, white in plumage due to absence of color enzyme

In this table the somatic colors shown by each of the sixteen zygotes is given in the second and fourth columns. For our purpose we can not perfectly distinguish between the blacks with red and those without because the red first appears at an age to which most chicks were not reared, also the red *shows* only in the cockerels. Summing, then, and combining all blacks, we get 9 black, to 4 white to 3 birds with the coloration of the Jungle Fowl or game. In 205 chicks expectation would consequently be: black 116, white 51, game 38. Actually there appeared: black 119, white 55, game 31. It will be seen that the observed numbers agree closely with theory and thus confirm the theory. Nothing is more startling than the appearance in this second hybrid generation from solid black and pure white grandparents of typical black-and-red game colored fowl.

I have shown that the appearance of the Jungle Fowl coloration accords with the factor hypothesis, but may not the result be explained with equal satisfaction on the old views, such as "the act of crossing in itself leads to the recovery of lost characters" or "two negatives make a positive." The principal objection to the view that crossing *per se* causes reversion is the fact that not all crosses give the same result. A black Minorca crossed with a white Leghorn produces only white offspring (with black specks in the pullets); and these hybrids bred together produce black and also white birds but no black-and-red! Stress has been laid upon the dissimilarity of the parents as a prerequisite of reversion; but black by white is certainly a dissimilar cross. On the other hand I crossed two *white* fowl—a white Leghorn (previously tested for purity of white) and a white silky. The offspring were at first white, but later the cockerels gained red on the wing-bars and other parts of the plumage. I then bred these hybrids together and got, among other things, as typical black-and-red game colored fowl as one could wish to see. Here from two similarly colored birds a so-called reversion is obtained, whereas none is yielded by black x white. Surely the cause of reversion is not dissimilarity of the parents *per se*.

To conclude, then, the old notion that hybridization, in and of itself, leads to a reversion to an ancestral condition should be abandoned; and in its place we have to accept the factor theory according to which two elements may, upon uniting, produce a new character. If in the ancestors these elements were united, the races having been evolved by separating the elements, then crossing the races will bring together again the elements and thus restore, so far as that one character goes, the ancestral condition.

A FEW PRELIMINARY EXPERIMENTS ON THE EFFECT OF THE AGE OF THE PARENTS UPON THE VIGOR OF CHICKENS.

BY PROF. HORACE ATWOOD, *Morgantown, W. Va.*

Early hatched pullets lay better in winter, when eggs are high in price, than old hens, and as a consequence on many egg farms practically all of the older hens are disposed of each summer and their place is taken by pullets hatched during the preceding spring. White this undoubtedly is good policy, from the standpoint of winter egg production, yet it has led in many cases into the practice of incubating the eggs of these pullets during the following spring, when the fowls are practically one year old. Is it a good plan to use such eggs for hatching? Are the