Mendel's Law and Heredity of Pigmentation in Mice*

by Lucien Cuénot

In 1865, Gregor Mendel pursuing hybridization experiments on peas, formulated clearly and completely a law of heredity, which was recently rediscovered and confirmed by de Vries, Correns, E. Tschermak, and Webber.

Suppose one crosses two plants which differ from each other in *n* characters, the most striking of which is, for example, the color of the flower. Let us call the color of one of the plants *a,* and *b* that of the other. If these characters follow Mendel's rule, the products of the crossing have an absolute uniformity: all the hybrids have the color *a*, without any trace of the hue of *b*; we then say that the character *a* is dominant, and that the character *b* is recessive (I would prefer the word dominated). If these hybrids are crossed between them, we obtain a second generation which differs from the previous one by the dimorphism of individuals: 75% of them have the dominant character *a*, and 25% the dominated character *b*.

To explain the reappearance of the dominated character, and the dimorphism of the descendants of hybrids, Mendel and Naudin, but the first with much more precision than the second, have thought that the antagonistic characters *a* and *b*, juxtaposed in the fertilized egg and no doubt in the somatic cells which descend from it, they disjoin in the gametes, which, consequently, are no longer hybrids[1]; half of them possess only the character *a*, the other half only the character *b*. When we cross hybrids between them, the following four combinations of gametes can be formed:

$$(a + a) \quad (a + b) \quad (b + a) \quad (b + b)$$

In the first three cases, the plant will have the dominant character *a*; in the fourth, the dominated character *b*; the plants from ($a + a$) and ($b + b$) possess the characteristics *a* and *b* at the state of purity, as the initial parents; ($a + b$) and ($b + a$) are hybrids identical to those resulting from the first cross. This very simple hypothesis of disjunction has been superabundantly verified by the various authors quoted above, and there is no doubt that it corresponds to the reality of the facts.

So far, research on the applications of Mendel's law has all been about the plant kingdom, and it is not known whether this mode of inheritance is also found in animals. For two years, I am experimenting on a very favorable material, which allows me to answer in the affirmative.

The most striking (and perhaps the only) differential characteristic between gray house mice (*Mus musculus* L.) and red-eyed albino mice is the presence of black and yellow pigment in the first, its complete absence in the second. Now, if we cross a gray mouse (male or female), with a white mouse (female or male), we always get, without exception, gray products. The character, pigmentation, is therefore dominant compared to the absence of pigment character[2].

If we call g the dominant character, and b the dominated character, the crossing products between gray and albino have the formula ($b + g$). I cross these gray halfbreeds; if there is disjunction in the gametes, the calculation of the probabilities teaches that the products of this second crossing must include:

$$n\,(g + g) + 2n\,(g + b) + n\,(b + b)$$

that is, 25% of albinos and 75% of gray, the latter comprising 25% pure gray ($g + g$) and 50% mixed gray ($g + b$), which it will be impossible to differentiate externally.

The experience is very much in agreement with this prediction: I obtained 270 pups, which include 198 grays and 72 albinos, or 26.6% of these. The albinos are of pure race, without a trace of gray: indeed, crossed between them, they always give, without exception, albinos. To demonstrate that there are purebred grays and mixed grays, it is a little more complicated than in plants, because we cannot resort to self-fertilization; I had to cross between them a certain number of these gray mice of the second generation, taken absolutely at random: according to the probabilities, about half of the couples gave me only gray (189), which proves that one or both parents had g gametes only; the other half of the couples gave me, at each litter, gray and white (162 gray and 57 albino), which proves that both parents had g and b gametes. This time again, according to the probabilities, the number of grays is triple that of the albinos (74 and 26%).

The disjunction of the characters in the gametes of gray and albino can be verified by another series of experiments: let's call a half-blood, following the example of the animal breeders, the gray mouse resulting from the cross between wild gray and albino; this half-blood, mated with an albino, give albino and gray mice with 3/4 white blood; a gray mouse of 3/4 blood, coupled with an albino, gives albinos and some gray, which have 7/8 of white blood, etc. Now, if there is a disjunction of the characters, we have crossed each time gametes with character b (those of the albino), by gametes b and g (those of the gray); and if the genital gland of this last contains as many gametes of the two types, we must always obtain, at each crossing, as many albinos ($b + b$) as grays ($b + g$). The experiments are perfectly consistent, this time again, with the theoretical prediction; for five successive generations, the repeated introduction of white blood, to speak animal breeder's language, does not diminish in any way the number of gray mice in litters.

The disjunction of the dominant and dominated characteristics makes it possible to predict and understand facts that appear paradoxical to breeders: an albino mouse, whose ancestors, for a number of generations as large as one wants, were gray, is however an albino of absolutely pure race, which will never present gray atavism. By crossing two gray mice, containing each n-1/n of white blood, n being as big as one wants, one can get absolutely pure gray mice ($g + g$), which will never return to the albinism.

I am convinced that in animal breeding we will find interesting applications of Mendel's law. When we know it better; its theoretical importance is considerable, and de Vries has clearly felt the support it gives to theories of heredity based on the hypothesis of representative particles. Finally, we see that two varieties of the same kind, which differ from each other only by a character subject to the law of Mendel, are incapable of mixing and of giving a mixed form, though indefinitely fecund between them; in the hierarchy of forms they thus occupy a special place, alongside the mixable and intermediate races, such as the White and the Negro, and species that are mixable, but quickly infertile, such as the horse and the donkey.

In my breedings, I obtained, incidentally, yellow, black, gray variegated with white and black variegated mice; I now seek to untangle the laws which govern the inheritance of these variations, laws which seem very different from that of Mendel.

Nancy, 13 March 1902.

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Author's Footnotes

[1]They are no longer hybrids in an absolute manner, if the two plants differ only by the characters *a* and *b*; if they differ by *n* non-correlative characters, the gametes are no longer hybrids only relative to the characters *a* and *b*, considered in particular.

[2]Many authors since Colladon (1824) have already made crosses between gray and albino mice, but they do not agree on the result; Haacke (1897) is the only one who, like me, has noticed the absolute preponderance of gray. To observe it, one must be careful to work with real gray mice, captured in the wild, and not with laboratory animals, which may have albinos in their ancestors.

Translators' Notes

This is the first report that Mendel's laws also applied to animals (the house mouse).

Cuénot reports the results of crosses between gray and white mice. More simply these crosses assess the inheritance of pigmentation. The characters *g* and *b* are abbreviations for the French words grise (gray) and blanc (white), respectively. *g* (pigmented) would be equivalent to the *Tyrosinase* alleles *C* or + and *b* (non-pigmented) would be equivalent to *c*. Thus, (*g* + *b*) = *C*/*c*, pigmented; (*g* + *g*) = *C*/*C*, pigmented; and (*b* + *b*) = *c*/*c*, albino.

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