CHAPTER VIII.

DISCUSSION OF THE DATA OF EYE COLOUR.

Preliminary Remarks.—Data.—Persistence of Eye-Colour in the Population.—Fundamental Eye-Colours.—Principles of Calculation.—Results.

Preliminary Remarks.—In this chapter I will test the conclusions respecting stature by an examination into hereditary Eye-colour. Supposing all female measures to have been transmuted to their male equivalents, it has been shown (1) that the possession of each unit of *peculiarity* of stature in a man [that is of each unit of difference from the average of his race] when the man's ancestry is unknown, implies the existence on an average of just one-third of a unit of that peculiarity in his "Mid-Parent," and consequently of the same amount in each of his parents; also just one-third of a unit in his Son; (2) that each unit of peculiarity in each ancestor taken singly, is reduced in transmission according to the following average scale;—a Parent transmits only $\frac{1}{4}$, and a Grand-Parent only $\frac{1}{16}$.

Stature and Eye-colour are not only different as qualities, but they are more contrasted in hereditary

behaviour than perhaps any other common qualities. Parents of different Statures usually transmit a blended heritage to their children, but parents of different Eye-colours usually transmit an alternative heritage. If one parent is as much taller than the average of his or her sex as the other parent is shorter, the Statures of their children will be distributed, as we have already seen, in nearly the same way as if the parents had both been of medium height. But if one parent has a light Eye-colour and the other a dark Eye-colour, some of the children will, as a rule, be light and the rest dark; they will seldom be medium eye-coloured, like the children of medium eye-coloured parents. The blending in Stature is due to its being the aggregate of the quasi-independent inheritances of many separate parts, while Eye-colour appears to be much less various in its origin. If notwithstanding this two-fold difference between the qualities of Stature and Eye-colour, the shares of hereditary contribution from the various ancestors are alike in the two cases, as I shall show that they are, we may with some confidence expect that the law by which those hereditary contributions are found to be governed, may be widely, and perhaps universally applicable.

Data.—My data for hereditary Eye-colour are drawn from the same collection of "Records of Family Faculties" ("R.F.F.") as those upon which the inquiries into hereditary Stature were principally based. I have analysed the general value of these data in respect to

Stature, and shown that they were fairly trustworthy. I think they are somewhat more accurate in respect to Eye-colour, upon which family portraits have often furnished direct information, while indirect information has been in other cases obtained from locks of hair that were preserved in the family as mementos.

Persistence of Eye-colour in the Population.—The first subject of our inquiry must be into the existence of any slow change in the statistics of Eye-colour in the English population, or rather in that particular part of it to which my returns apply, that ought to be taken into account before drawing hereditary conclusions. For this purpose I sorted the data, not according to the year of birth, but according to generations, as that method best accorded with the particular form in which all my R.F.F. data are compiled. Those persons who ranked in the Family Records as the "children" of the pedigree, were counted as generation I.; their parents, uncles and aunts, as generation II.; their grandparents, great uncles, and great aunts, as generation III.; their great grandparents, and so forth, as generation IV. No account was taken of the year of birth of the "children," except to learn their age; consequently there is much overlapping of dates in successive generations. We may however safely say, that the persons in generation I. belong to quite a different period to those in generation III., and the persons in II. to those in IV. I had intended to exclude all children under the age of eight years, but in this particular branch of the inquiry, I

fear that some cases of young children have been accidentally included. I would willingly have taken a later limit than eight years, but could not spare the data that would in that case have been lost to me.

A great variety of terms are used by the various compilers of the "Family Records" to express Eye-colours. I began by classifying them under the following eight heads;—1, light blue; 2, blue, dark blue; 3, grey, blue-green; 4, dark grey, hazel; 5, light brown; 6, brown; 7, dark brown; 8, black. Then I constructed Table 15.

The diagram, page 143, clearly conveys the significance of the figures in Table 15. Considering that the groups into which the observations are divided are eight in number, the observations are far from being sufficiently numerous to justify us in expecting clean results; nevertheless the curves come out surprisingly well, and in accordance with one another. There can be little doubt that the change, if any, during four successive generations is very small, and much smaller than mere memory is competent to take note of. I therefore disregard a current popular belief in the existence of a gradual darkening of the British population, and shall treat the eye-colours of those classes of our race who have contributed the records, as having been statistically persistent during the period under discussion.

The concurrence of the four curves for the four several generations, affords internal evidence of the trustworthiness of the data. For supposing we had

curves that exactly represented the true Eye-colours for the four generations, they would either be concurrent or they would not. If these curves were concurrent, the errors in the R.F.F. data must have been so curiously distributed as to preserve the concurrence. If these curves were not concurrent, then the errors in the R.F.F. data must have been so curiously distributed as to neutralise the non-concurrence. Both of these suppositions are improbable, and we must conclude that the curves really agree, and that the R.F.F. errors are not large enough to spoil the agreement. The close similarity of the two curves, derived respectively from the whole of the male and the whole of the female data, and the more perfect form of the curve derived from the aggregate of all the cases, are additional evidences in favour of the goodness of the data on the whole.

Fundamental Eye-colours.—It is agreed among writers (*cf.* A. de Candolle, see footnote overleaf) that the one important division of eye-colours is into the light and the dark. The medium tints are not numerous, but may be derived from any one of four distinct origins. They may be hereditary with no notable variation, they may be varieties of light parentage, they may be varieties of dark parentage, or they may be blends. Medium tints are classed in my list under the heading "4. Dark grey, hazel;" these form only 12·7 per cent. of all the observed cases. In medium tints, the outer portion of the iris is often of a dark grey colour,

Percentages of the Various Eye-colours in Four Successive Generations.

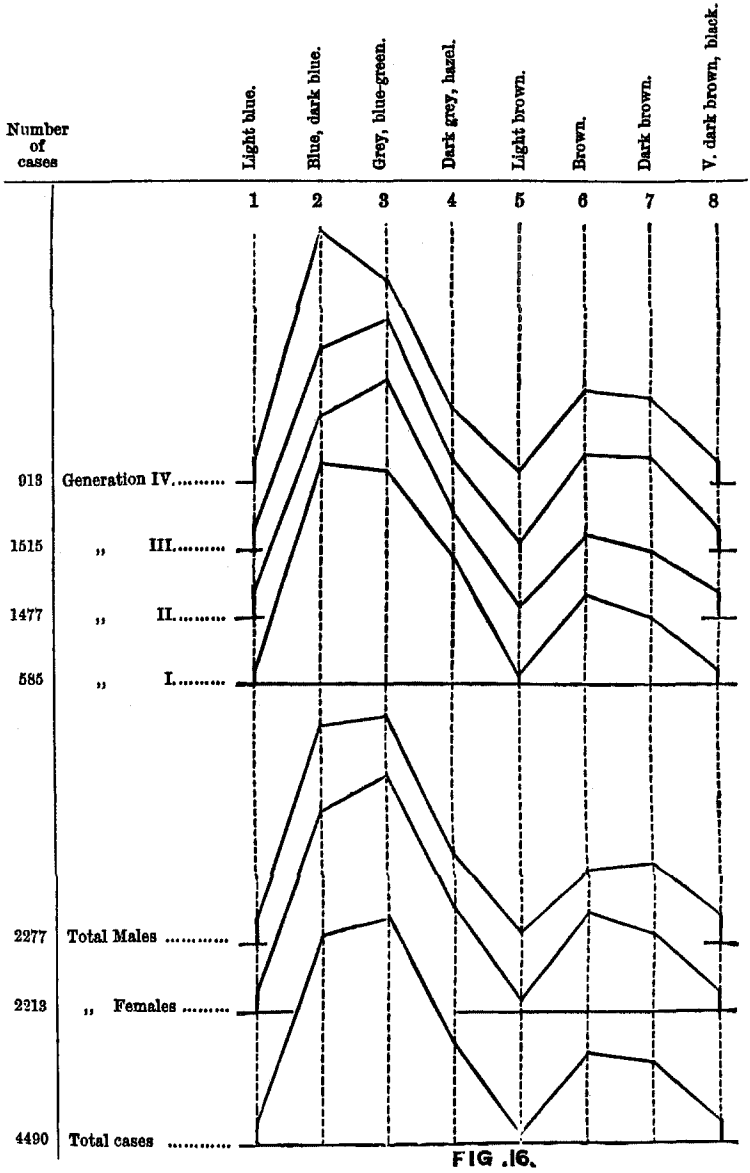

FIG. 16.

and the inner of a hazel. The proportion between the grey and the hazel varies in different cases, and the eye-colour is then described as dark grey or as hazel, according to the colour that happens most to arrest the attention of the observer. For brevity, I will henceforth call all intermediate tints by the one name of hazel.

I will now investigate the history of those hazel eyes that are variations from light or from dark respectively, or that are blends between them. It is reasonable to suppose that the residue which were inherited from hazel-eyed parents, arose in them or in their predecessors either as variations or as blends, and therefore the result of the investigation will enable us to assort the small but troublesome group of hazel eyes in an equitable proportion between light and dark, and thus to simplify our inquiry.

The family records include 168 families of brothers and sisters, counting only those who were above eight years of age, in whom one member at least had hazel eyes. For distinction I will describe these as "hazel-eyed families;" not meaning thereby that all the children have that peculiarity, but only one or more of them. The total number of the brothers and sisters in the 168 hazel-eyed families is 948, of whom 302 or about one-third have hazel eyes. The eye-colours of all the 2×168, or 336 parents, are given in the records, but only those of 449 of the grandparents, whose number would be 672, were it not for a few cases of cousin marriages. Thus I have information concerning

about only two-thirds of the grandparents, but this will suffice for our purpose. The results are given in Table 16.

It will be observed that the distribution of eye-colour among the grandparents of the hazel-eyed families is nearly identical with that among the population at large. But among the parents there is a notable difference; they have a decidedly larger percentage of light eye-colour and a slightly smaller proportion of dark, while the hazel element is nearly doubled. A similar change is superadded in the children. The total result in passing from generations III. to I., is that the percentage of the light eyes is diminished from 60 or 61 to 45, therefore by one quarter of its original amount, and that the percentage of the dark eyes is diminished from 26 or 27 to 23, that is by about one-eighth of its original amount, the hazel element in either case absorbing the difference. It follows that the chance of a light-eyed parent having hazel offspring, is about twice as great as that of a dark-eyed parent. Consequently, since hazel is twice as likely to be met with in any given light-eyed family as in a given dark-eyed one, we may look upon two-thirds of the hazel eyes as being fundamentally light, and one-third of them as fundamentally dark. I shall allot them rateably in that proportion between light and dark, as nearly as may be without using fractions, and so get rid of them. M. Alphonse de Candolle[1] has

[1] Hérédité de la Couleur des Yeux dans l'Espèce humaine," par M. Alphonse de Candolle. "Arch. Sc. Phys. et Nat. Geneva," Aug. 1884, 3rd period. vol. xii. p. 97.

also shown from his data, that *yeux gris* (which I take to be the equivalent of my *hazel*) are referable to a light ancestry rather than to a dark one, but his data are numerically insufficient to warrant a precise estimate of the relative frequency of their derivation from each of these two sources.

In the following discussion I shall deal only with those fraternities in which the Eye-colours are known of the two Parents and of the four Grand-Parents. There are altogether 211 of such groups, containing an aggregate of 1023 children. They do not, however, belong to 211 different family stocks, because each stock which is complete up to the great grand-parents inclusive (and I have fourteen of these) is capable of yielding three such groups. Thus, group 1 contains *a*, the "children;" *b*, the parents; *c*, the grand-parents. Group 2 contains *a*, the father of the "children" and his brothers and his sisters; *b*, the parents of the father; *c*, the grand-parents of the father. Group 3 contains the corresponding selections on the mother's side. Other family stocks furnish two groups. Out of these and other data, Tables 19 and 20 have been made. In Table 19 I have grouped the families together whose two parents and four grand-parents present the same combination of Eye-colour, no group, however, being accepted that contains less than twenty children. The data in this table enable us to test the *average* correctness of the law I desire to verify, because many persons and many families appear in the same group, and individual peculiarities

tend to neutralise each other. In Table 20 I have separately classified on the same system all the families, 78 in number, that consist of six or more children. These data enable us to test the trustworthiness of the law as applied to *individual* families. It will be seen from my way of discussing them, that smaller fraternities than these could not be advantageously dealt with.

It will be noticed that I have not printed the number of dark-eyed children in either of these tables. They are implicitly given, and are instantly to be found by subtracting the number of light-eyed children from the total number of children. Nothing would have been gained by their insertion, while compactness would have been sacrificed.

The entries in the tables are classified, as I said, according to the various combinations of light, hazel, and dark Eye-colours in the Parents and Grand-Parents. There are six different possible combinations among the two Parents, and 15 among the four Grand-Parents, making 6×15, or 90 possible combinations altogether. The number of observations are of course by no means evenly distributed among the classes. I have no returns at all under more than half of them, while the entries of two light-eyed Parents and four light-eyed Grand-Parents are proportionately very numerous.

The question of marriage selection in respect to Eye-colour, has been already discussed briefly in p. 86. It is a less simple statistical question than at a first sight it may appear to be, so I will not discuss it farther.

Principles of Calculation.—I have next to show how the expectation of Eye-colour among the children of a given family is to be reckoned on the basis of the same law that held in respect to stature, so that calculations of the probable distribution of Eye-colours may be made. They are those that fill the three last columns of Tables 19 and 20, which are headed I., II., and III., and are placed in juxtaposition with the observed facts entered in the column headed "Observed." These three columns contain calculations based on data limited in three different ways, in order the more thoroughly to test the applicability of the law that it is desired to verify. Column I. contains calculations based on a knowledge of the Eye-colours of the Parents only; II. contains those based on a knowledge of those of the Grand-Parents only; III. contains those based on a knowledge of those both of the Parents and of the Grand-Parents, and of them only.

I. Eye-colours given of the two Parents—

Let the letter S be used as a symbol to signify the subject (or person) for whom the expected heritage is to be calculated. Let F stand for the words "a parent of S;" G_1 for "a grandparent of S;" G_2 for "a great-grandparent of S," and so on.

We must begin by stating the problem as it would stand if Stature was under consideration, and then modify it so as to apply to Eye-colour. Suppose then, that the amount of the peculiarity of Stature possessed by F is equal to D, and that nothing whatever

is known with certainty of any of the ancestors of S except F. We have seen that though nothing may actually be known, yet that something definite is implied about the ancestors of F, namely, that each of his two parents (who will stand in the order of relationship of G_1 to S) will on the average possess $\frac{1}{3}$D. Similarly that each of the four grandparents of F (who will stand in the order of G_2 to S) will on the average possess $\frac{1}{9}$D, and so on. Again we have seen that F, on the average, transmits to S only $\frac{1}{4}$ of his peculiarity; that G_1 transmits only $\frac{1}{16}$; G_2 only $\frac{1}{64}$, and so on. Hence the aggregate of the heritages that may be expected to converge through F upon S, is contained in the following series :—

$$D\left\{\frac{1}{4}+2\left(\frac{1}{3}\times\frac{1}{2^4}\right)+4\left(\frac{1}{9}+\frac{1}{2^6}\right)+\ \&c.\ \right\}$$
$$=D\left\{\frac{1}{2^2}+\frac{1}{2^3.3}+\frac{1}{2^4.3^2}+\ \&c.\ \right\}=D\times 0{\cdot}30.$$

That is to say, each parent must in this case be considered as contributing 0·30 to the heritage of the child, or the two parents together as contributing 0·60, leaving an indeterminate residue of 0·40 due to the influence of ancestry about whom nothing is either known or implied, except that they may be taken as members of the same race as S.

In applying this problem to Eye-colour, we must bear in mind that the fractional chance that each member of a family will inherit either a light or a dark Eye-colour, must be taken to mean that that same fraction

of the total number of children in the family will probably possess it. Also, as a consequence of this view of the meaning of a fractional chance, it follows that the residue of 0·40 must be rateably assigned between light and dark Eye-colour, in the proportion in which those Eye-colours are found in the race generally, and this was seen to be (see Table 16) as 61·2 : 26·1 ; so I allot 0·28 out of the above residue of 0·40 to the heritage of light, and 0·12 to the heritage of dark. When the parent is hazel-eyed I allot $\frac{2}{3}$ of his total contribution of 0·30, *i.e.*, 0·20 to light, and $\frac{1}{3}$, *i.e.* 0·10 to dark. These chances are entered in the first pair of columns headed I. in Table 17.

The pair of columns headed I. in Table 18 shows the way of summing the chances that are given in the columns that have a similar heading in Table 17. By the method there shown, I calculated all the entries that appear in the columns with the heading I. in Tables 19 and 20.

II. Eye-colours given of the four Grand Parents—

Suppose D to be possessed by G_1 and that nothing whatever is known with certainty of any other ancestor of S. Then it has been shown that the child of G_1 (that is F) will possess $\frac{1}{2}$D ; that each of the two parents of G_1 (who stand in the relation of G_2 to S) will also possess $\frac{1}{3}$D ; that each of the four grandparents of G_1 (who stand in the relation of G_3 to S) will possess $\frac{1}{9}$D, and so on. Also it has been shown that the shares of their several peculiarities that will on the average be transmitted by F, G_1, G_2, &c., are $\frac{1}{4}$, $\frac{1}{16}$, $\frac{1}{64}$, &c.,

respectively. Hence the aggregate of the probable heritages from G_1 are expressed by the following series :—

$$D\left\{\frac{1}{3}\times\frac{1}{2^2}+1\times\frac{1}{2^4}+\frac{1}{3}\times 2\times\frac{1}{2^6}+\frac{1}{9}\times 4\times\frac{1}{2^8}+\&c.\right\}$$

$$= D\left\{\frac{1}{12}+\left(\frac{1}{2^4}+\frac{1}{3\times 2^5}+\frac{1}{3^2\times 2^6}+\&c.\right)\right\}=D\times\left(\frac{1}{12}+\frac{3}{40}\right)=D\times 0{\cdot}16.$$

So that each grandparent contributes on the average 0·16 (more exactly 0·1583) of his peculiarity to the heritage of S, and the four grandparents contribute between them 0·64, leaving 36 indeterminate, which when rateably assigned gives 0·25 to light and 0·11 to dark. A hazel-eyed grandparent contributes, according to the ratio described in the last paragraph, 0·10 to light and 0·06 to dark. All this is clearly expressed and employed in the columns II. of Tables 17 and 18.

III. Eye-colours given of the two Parents and four Grand-Parents—

Suppose F to possess D, then F taken alone, and not in connection with what his possession of D might imply concerning the contributions of the previous ancestry, will contribute an average of 0·25 to the heritage of S. Suppose G_1 also to possess D, then his contribution together with what his possession of D may imply concerning the previous ancestry, was calculated in the last paragraph as $D\times\frac{3}{40}=D\times 0{\cdot}075$. For the convenience of using round numbers I take this as $D\times 0{\cdot}08$. So the two parents contribute between

them 0·50 of the peculiarity of S, the four grand-parents together with what they imply of the previous ancestry contribute 0·32, being an aggregate of 0·82, leaving a residue of 0·18 to be rateably assigned as 0·12 to light, and 0·6 to dark. A hazel-eyed Parent is here reckoned as contributing 0·16 to light and 0·9 to dark; a hazel-eyed Grand-Parent as contributing 0·5 to light and 0·3 to dark. All this is tabulated in Table 17, and its working explained by an example in the columns headed III. of Table 18.

Results.—A mere glance at Tables 19 and 20 will show how surprisingly accurate the predictions are, and therefore how true the basis of the calculations must be. Their *average* correctness is shown best by the totals in Table 19, which give an aggregate of calculated numbers of light-eyed children under Groups I., II., and III. as 623, 601, and 614 respectively, when the observed numbers were 629; that is to say, they are correct in the ratios of 99, 96, and 98 to 100.

Their trustworthiness when applied to *individual* families is shown as strongly in Table 20 whose results are conveniently summarised in Table 21. I have there classified the amounts of error in the several calculations: thus if the estimate in any one family was 3 light-eyed children, and the observed number was 4, I should count the error as 1·0. I have worked to one place of decimals in this table, in order to bring out the different shades of trustworthiness in the three sets of calculations, which thus become very apparent. It will be

seen that the calculations in Class III. are by far the most precise. In more than one-half of those calculations the error does not exceed 0·5, whereas in more than three-quarters of those in I. and II. the error is at least of that amount. Only one-quarter of Class III., but somewhere about the half of Classes I. and II., are more than 1·1 in error. In comparing I. with II., we find I. to be slightly but I think distinctly the superior estimate. The relative accuracy of III. as compared with I. and II., is what we should have expected, supposing the basis of the calculations to be true, because the additional knowledge utilised in III., over what is turned to account in I. and II., must be an advantage.

My returns are insufficiently numerous and too subject to uncertainty of observation, to make it worth while to submit them to a more rigorous analysis, but the broad conclusion to which the present results irresistibly lead, is that the same peculiar hereditary relation that was shown to subsist between a man and each of his ancestors in respect to the quality of Stature, also subsists in respect to that of Eye-colour.