Aspects of Physical and Mental Inheritance.[1]

By Prof. R. RUGGLES GATES.

ONE of the most striking facts in modern biology is the discovery that hereditary differences commonly behave as independent fixed units, handed on generation after generation according to various characteristic but simple laws. The differences so transmitted may be large or they may be very minute, but they in some way maintain their identity throughout the welter of events which constitute the passage from one generation of adults to another: that is, the maturation of the germ cells and the development of the individual. Clearly a physical difference maintained in successive generations among individuals developing in the same environment must be due to an initial difference in the germinal material. Such differences are, moreover, as a rule equally inherited through either the egg or the sperm in crosses. The only structural materials in the germ cells of higher organisms which fulfil these requirements for transmission are the chromosomes.

These minute bodies in the nucleus evidently constitute the essential nexus between generations, in so far as the widespread Mendelian differences are concerned, but in plants certain characters may be controlled by plastids in the cytoplasm. It has furthermore been proved in certain plants and animals that visible differences in the chromosomes are accompanied by external differences in the resulting organism. Just as the cell theory of organic structure long ago emerged into fact, so the chromsome theory of inheritance has become a fact. This does not mean, however, that the chromosomes alone are concerned in inheritance.

An abundance of evidence from many sources leads to the view that the chromosome is a complicated structure composed of smaller units. The theory that these units or genes are arranged in linear fashion in the chromosomes, has been connected chiefly with the name of Morgan, because of his extensive studies of heredity and mutation in the fruit-fly, Drosophila; but its origin is really much older. While this theory of linear arrangement is not yet established, it may be said that no other reasonable theory has yet been put forward to explain the phenomena of crossing-over which have been so extensively investigated in this fly, and to a lesser extent in various other organisms.

We have, then, a picture of the chromosomes as containing large numbers of differentiated areas or groups of particles which, while in the uncompacted state, activate and control or determine the growth and differentiation of the cytoplasm and hence the development of the individual. Such conceptions are necessary to explain the unitary behaviour in inheritance of innumerable characteristics in man as well as in other organisms.

While, however, the units must be abstracted and considered separately for purposes of investigation, yet they form the elements of an extraordinarily complicated system and they cannot exist apart from it. Eyes may be blue or brown, and the difference is inherited as a unit, but the blue eye can only develop as a part of the whole system to which it belongs.[2] Here I am in fundamental agreement with the views expressed by Dr. Myers. Just as the developed character cannot exist apart from the organism to which it belongs —you cannot separate the serration from a leaf margin or the shape of the nose from that organ—so in the germplasm the various structural elements making up the configuration, though each produces its own effect through chemical action or structural arrangement, are interdependent in the system to which they belong. Mendelian inheritance consists in the substitution of one such unit for another which occupies the corresponding position in the architecture of the germplasm.

The phenomena of heredity are made possible by these structural arrangements within the organism, the body being composed of cells each with its nucleus, that nucleus containing two sets of chromosomes of corresponding structure, one derived from each parent. Thus are we woven out of the warp and woof derived by mitotic division from two parental sex cells, making a garment infinitely finer in texture and more intimately blended in its structural elements than any fabric. Yet the fact remains that these elements maintain their identity and usually segregate out again sharply when new germ cells are formed.

The orderliness of development in its minutest details, the interrelations and interfunctionings of the chemical and structural elements as they arise, impress every biologist deeply with their regularity and stability. The phenomena of individual development are thus as remarkable in some respects as those of evolution itself. In heredity all these potentialities of the organism must pass over the very narrow bridge of the two germ cells, one of which contributes little more than a nucleus. How this miracle of orderly development is accomplished we can only dimly picture in detail. But the ubiquitous facts of heredity continually emphasise the amazing orderliness of development.

It is sometimes stated that the clear-cut segregation which is so characteristic of Mendelian heredity applies only to abnormalities, and that normal racial and specific differences do not follow such laws. The fact that related species often differ visibly in their chromosome equipment certainly leads to many departures which may more or less completely obscure Mendelian phenomena in crossing. De Vries formerly took up the position that species and varieties differ in their behaviour on crossing. But there is nothing in the more recent work to show that such differences as exist are really fundamental in our present point of view, although they are certainly important. Variety differences are often single sharp units, while specific differences are more apt to represent accumulations of many, often multiple, differences, or chromosome differences which have come about in other ways than by simple Mendelian mutations. Interspecific sterility,

[1] Contribution to a joint discussion on "Heredity in its Physical and Mental Aspects," before Sections D (Zoology), H (Anthropology), and J (Psychology) of the British Association at Oxford on August 9.

[2] That this does not necessarily include the whole organism is shown by the recent tissue culture work of Strangeways and Fell, in which eye rudiments excised from embryo chicks continued their development.

however, all too frequently prevents crosses being made from which evidence of the nature of the differences could be obtained. There is some evidence, however, both in animals and plants, that in related species the germplasm is similarly constituted.

In the case of man, there is no evidence that the process of inheritance of racial characters differs in any important respect from that of abnormalities. In eye colour—a typical racial character—blue and brown have long been regarded as a Mendelian pair, and while different degrees of brown exist, there is evidence that each segregates sharply from blue. In my book "Heredity and Eugenics" the inheritance of a large number of abnormalities was considered, each following its own Mendelian law.

More recently I have considered the inheritance of racial differences[3] in man. Here multiple factors appear often to be characteristic, as in skin colour and stature. But everything indicates that inheritance of stature and cephalic index follows the same rules as the inheritance of size and shape in other organisms. Present knowledge indicates that the size factors in man differ in no important respect from those of rabbits or even of plants. Moreover, there is every indication that in interracial crosses, where stature and cephalic index are usually regarded as racial diagnostic features, the laws of inheritance of these differences are exactly the same as within a single human family. The more recent investigations indicate that far too much importance has been attached to cephalic index as a racial character, and the same is true to a lesser extent of stature. But it will be some time before a satisfactory analysis of head shape in terms of size and shape factors can be attempted.

Turning now for a moment to mental inheritance, I do not propose to discuss any of the philosophical views of the relations between mind and body, although I am inclined to adopt some such interpretation as that of Lloyd Morgan, namely, that the life of the organism can equally be viewed as a system of physiological or of mental events, without solving or attempting to solve the problem of their interrelations the one to the other. But from the biological point of view, as Prof. Dendy wrote, "It is only in so far as they are related to the brain [I should prefer to say the nervous system] that the discussion of the inheritance of mental characters can have any meaning." The analogy which is sometimes drawn between heredity and memory is really an attempt to explain the less obscure by comparison with the more obscure, or from the point of view just expressed it represents a jump from the physiological to the mental interpretation instead of adhering consistently to one or the other.

In one sense mental and physical inheritance are on exactly the same basis, for in both cases inheritance can only be determined by comparing parents with offspring or the latter with each other, and noting similarities and differences. Such comparisons lead to the clearest evidence of mental inheritance. But it should be recognised that observation of the fact of inheritance is one thing and explanation of how it comes about is quite another. Owing to the difficulty of defining and determining mental characters, progress in the study of mental inheritance has been retarded. Probably few psychologists would now deny the fact of mental inheritance, but biologists must look to them for an analysis of the mind which will enable us to determine what are the units which are really being inherited. Psychologists themselves are only beginning to consider these questions. McDougall's work has been most useful in the preliminary analysis of mental differences from a biological point of view.

When Galton began his studies of mental inheritance the faculty psychology was current, and he naturally made use of its conceptions. But now that the conception of the mind as made up of faculties has become obsolete and various other methods of analysis have taken its place, we still need an analysis of the mind which will be more biological in its characterisation. McDougall writes of the "structure of the mind," but scarcely in the sense in which a biologist would hope to see the term used.

There appear to be two possible lines of approach to a biological analysis of the mind from an hereditary point of view: (1) By the study of mental evolution; (2) by comparison of the mentality of related individuals. As regards mental evolution, the study of animal behaviour shows that increasing complexity of the nervous system is paralleled by increasing mental complexity or powers of reaction. This is clear to any one who compares, for example, a Paramœcium, a starfish, and an ape. Elliot Smith has pointed out in some detail how the mental evolution of man himself has taken place through increasing complication in the structure of the fore-brain. The mind has become an instrument for the recognition, confluence and co-ordination of relationships.

That many mental differences are the result of germinal variations arising in the nervous system is indicated by such extreme cases as (*a*) tumbler pigeons, (*b*) a race of goats which becomes partially paralysed when frightened,[4] and (*c*) in man, feeblemindedness. It is questionable in how far any other source of mental variations is required to explain mental evolution. The cases cited are semi-pathological, but the smaller, normal differences which have been less studied are likely to show similar origin and hereditary behaviour.

There are no doubt many ways in which the human mind can be analysed and its elements classified; but I believe it will be found with mental, as with physical, inheritance that the only way to determine what are the inherited units is by comparing the mentality of parents with that of their children and relatives. The difficulties of such comparison are of course increased by the facts of proximity and imitation. But the *differences* which appear will often be more significant than the similarities. We have already seen that studies of physical heredity require that the organisms should develop in a similar environment. Obviously the same is true of mental inheritance; but as individuals develop they choose their own mental environment according to their inherited

[3] "Mendelian Heredity and Racial Differences," *Journ. Roy. Anthrop. Inst.*, **55**, 468-482, 1926.

[4] It appears not improbable that the 'death-feigning' instinct of certain insects and other animals has arisen in a similar way through germinal variations in the nervous system.

tastes and aptitudes. In the biographies of great men it often appears that escape from their early environment was their only means of finding self-expression for their inherited mental qualities.

From the point of view I am expressing, mental inheritance is just as real as physical inheritance, and a suitable mental environment is just as necessary for the development of mental characters as a suitable physical environment is for the development of physical characters. Further, the mental environment is extremely complex and intimate in the way it impinges upon the developing individual. One of the remarkable things about organisms, however, is the stability they often show under altered conditions of development, and this appears to be as true of mental as of physical characters. Mental tests apparently show that inherent intelligence, for example, does not develop or grow with the growth of the individual.

Another method by which mental inheritance has been studied is by the comparison of the mentality of identical twins. Galton, the pioneer in this field, cites many remarkable cases of such similarity, in some of which the twins were separated. More recently, many cases have been studied in some of which the separation took place at an early age, making it possible to study the effects of differences in upbringing upon the mental development and the innate abilities. While the mental environment is by no means negligible, and is often profound in its effects on the early development of the mentality, yet it seems clear that innate, *i.e.* inherited, differences persist, which are little if at all affected by the circumstances of life.

There is another matter which, I believe, adds greatly to the complexity of human behaviour. In 1923 I first suggested that when the individual is germinally heterozygous for a pair of contrasted character traits, they may both come into expression in his activities at different times. Indeed, this appears more likely than that there should be complete dominance of a mental character over its allelomorph. I am now looking upon traits of character as different methods of reacting in given circumstances. Since every one is doubtless heterozygous for many such character differences, this would help to account for some of the complexities as well as inconsistencies in human behaviour. Cases of multiple personality are possibly to be explained as more extreme examples of the same kind.

Finally, I should like to reiterate that what is most required now in the study of mental inheritance is an analysis of the mind by psychologists from an inheritance point of view. Psychologists have been so engrossed with the mind as such in its manifold activities that they appear to have neglected the kind of comparative psychology of individuals which is necessary for this purpose.

The Relation between Velocity of Wind and Wave.

By Dr. VAUGHAN CORNISH.

MANY years ago an investigation was begun by me to determine the relative velocity of wind and wave in deep water when the former has operated for a sufficient time to produce a constant condition, and with sufficient sea-room. The results are given in the *Quarterly Journal of the Royal Meteorological Society* for April last, and, at the invitation of the Editor of NATURE, some of the points of interest are brought together in this article.

The relation between velocity and period of deep-sea waves given by the ordinary formula for waves of infinitesimal height, namely, velocity in statute miles per hour = period in seconds multiplied by 3·493 agrees with that observed for ocean waves of conspicuous dimensions [1] sufficiently for the discussion of phenomena so numerous and irregular.

By timing the rise and fall of spots of spent foam upon the water, it is possible to determine from on board ship the period of both the wind-waves and of swell running at the time, whether crossing or concurrent. Employing this method I have never recorded waves with a speed greater than that of the wind, as has been done by other observers, an anomalous result which I attribute to mistaking a heavy swell for the wave when they are concurrent. Observations on a river at turn of tide, when the foam-spots were carried by the current first down-wind and then up-wind, have shown that their wind-drift is small relatively to the other magnitudes concerned.[2]

In the course of a voyage between Trinidad and Ushant, in very deep water all the time and free from considerable currents on every day but one, the speed of the waves was compared with the average speed maintained by the wind *for one hour or more*, as recorded by a Robinson anemometer fully exposed upon the bridge. When there was no crossing swell to interfere with the development of the waves, their speed was only 1·85 statute miles per hour less than that of wind, which had a sustained average velocity of 20 miles per hour. Thus there was blowing over the wave-crests only a 'light air,' the 'force 1' of Beaufort's scale, sufficient to drift the smoke issuing from a chimney but not strong enough to give direction to a wind-vane.

When hove-to in the Bay of Biscay in the storm of December 21, 1911, I determined the speed of the waves as 47·15 miles per hour, when the velocity of the wind, according to the logged Beaufort number, was 52·5 m.p.h. During the exceptionally stormy winter of 1898–99, when I was living within sight of the beach of Bournemouth Bay, the greatest period of a long-sustained series of breakers was 19 seconds, corresponding to a speed in deep water of 66·4 m.p.h. This was recorded on the afternoon of December 29. Gales in the North Atlantic from December 25 to December 29 were logged at 11 and 12 of Beaufort's scale, which correspond to wind velocity of 68 and greater than 75 miles per hour respectively. The greatest wind velocity on land during this winter, as recorded by instruments, was 70-76 miles per hour sustained for one hour.

The breakers above referred to, which were 139 in number and occupied three-quarters of an hour in arrival, were preceded in the morning by five groups

[1] See the author in *Jour. Roy. Soc. Arts*, Nov. 1, 1912, "Ocean Waves," and the *Field*, Feb. 13 and 27, 1915, "The Measurement of Waves at Sea."
[2] See papers by the author, British Association Report, Section A, Birmingham meeting, 1913, "On a Simple Method of Determining the Period of Waves at Sea," and *Q. J. Roy. Met. Soc.*, Apr. 1926, "Observations of Wind, Wave and Swell on the North Atlantic Ocean."