some evidence that the constituent parts of a molecule which are simultaneously separated are proportionate to atomic weights.

5. Atomic combining capacity. The modern doctrine of types and substitutions is solely based on the individuality of the atom, without which the whole fabric of typical structures must fail.

6. Ionism. The fact that bodies containing the same elements, and in precisely the same proportions, exhibit different properties, has been thus far accounted for, only on the supposition that atoms are differently arranged, but by no means all. Apart from the question of radicals, we may ascertain the number of different bodies which can be formed from the same number of different atoms, by an application of the mathematical law of permutations.

7. Homogeneity. The uniformity of structure and appearance of any element or chemical combination of elements furnishes the most palpable proof of the identity in size and shape of those definite parts which we designate as molecules. This homogeneity is retained under different degrees of pressure, thus making it apparent that molecules are not identical in structure, but that they approach and recede in precisely the same manner under the same conditions.

Finally.—The foregoing statement regarding the existence of atoms which are indivisible and indestructible under the ordinary conditions of life, does not preclude the supposition that the atom may be a cluster of smaller particles held together by a powerful affinity, which, when counteracted, would leave them free to move within a given sphere. On this assumption it is highly probable that the relative position of such particles may modify the atomic force. Moreover, the normal motion of such particles may determine not only the peculiarities of atomic spectra, but produce other effects not dependent on the amplitude of atomic oscillations, thus favouring the inference that the atom itself is a receptacle of force.

SAUL D. TILLMAN

BLOOD-RELATIONSHIP

I propose in this memoir to deduce by fair reasoning from acknowledged facts a more definite notion than now exists of the meaning of the word “Kinship.” It is my aim to analyze and describe the complicated connection that binds an individual, hereditarily, to his parents and to his brothers and sisters, and, therefore, by an extension of similar links, to his more distant kinsfolk. I hope by these means to set forth the doctrines of heredity in a more orderly and explicit manner than is otherwise practicable.

From the well-known circumstance that an individual may transmit to his descendants ancestral qualities which he does not himself possess, we are assured that the whole family, so to say, however much it may be displaced and replaced in chemical combinations, it invariably retains its characteristic weight. This invariability of weight is an essential property of the atom.

2. Atomic Volume. Gases unite in equal volumes or multiple volumes. If hydrogen be taken as unity, the density of each elementary gas is identical with the weight of its atom. The atomic volume, determined by dividing the atomic weight of a body by its specific gravity, has been the means of revealing many interesting relations among compounds of similar structure, and among many containing different components and of unlike structure.

3. Atomic Heat. It has been shown by experiment that quantities of each element conforming with its atomic number have the same capacity for heat, excepting only carbon, boron, and silicon; these, it is believed, will yet be found to conform to the law, that the specific heats of atoms are the same. This law is regarded as a direct confirmation of atomic weights.

4. Molecules. According to the atomic theory chemical forces are brought into equilibrium when atoms combine and form a molecule. Every gas and every body, decomposed by a density proportional to its molecular weight. All known molecular combinations and combining proportions are in accordance with the atomic doctrine. Decomposition by electrolysis affords

* A Treatise on the Diseases which produce the Organisation of Plants. By John William Draper. (New York: Harper and Brothers, 1843.)

† Fogg, Annalen, 1871, No. 10.

I will now proceed to consider the quality of the several relationships by which the above terms are connected together. The observed facts of Reversion enable us to prove that the latent elements must be greatly more varied than that of the personal or patient. The argument is as follows:—(1) There

* Read before the Royal Society, June 13, by Francis Galton, F.R.S.
must be room for very great variety, because a single strain of impure blood will reassert itself after more than eight generations; (2) an individual has 235 progenitors in the eighth degree, if there have been no ancestral intermarriages, while under the ordinary conditions of social and neighbourly life, he will certainly have had a considerable, though a smaller, number. (3) the gradual waning of the tendency to reversion as the generations increase, conforms to what would occur if each fresh marriage contributed a competing element for the same place, thus reducing the impure strain until its relative importance was reduced to an insignificantly amount.

It follows from these considerations that for each place among the personal elements there may exist, and probably often does exist, a very great variety of latent elements that formerly competed to fill it.

It has been the primary elements as they exist in the newly-impregnated ovum, where they are structureless, that contain the materials out of which structure is evolved. The embryonic elements are segregated from among them. On what principle are they segregated? Clearly it is on some principle of correlation. Thus far the phrase “Class Representation,” using that phrase in a perfectly general sense, as indicating a mere fact, and avoiding any hypothesis or affirmation on points of detail, about most, if not all, of which we are profoundly ignorant. I give as broad elements, that to the expression as a politician would give to the kindred one, “incidental and considerable.” By this he means to say that the assembly consists of representatives from the several constituencies, which is a distinct piece of information so far as it goes, and is a useful one, although it deals with no matter of detail. It is by thinking about the number of electors, their qualifications, or the manner in which they are influenced; it gives no information as to the number of seats; it does not tell how many candidates there are usually for each seat, nor whether the same person is eligible for, or may represent at the same time, more than one place, nor whether the result of the elections at one place may not influence those at another (on the principle of correlation). After these explanations the trust, he has no difficulty in accepting my definition of the general character of the relation between the embryonic and the structureless elements, the former are the result of election from the latter on some method of Class Representation.

The embryonic elements are developed into the adult person. “Development” is a word whose meaning is quite as distinct in respect to form, and as vague in respect to detail, as the phrase “Class Representation,” using that phrase in a perfectly general sense, as indicating a mere fact, and avoiding any hypothesis or affirmation on points of detail, about most, if not all, of which we are profoundly ignorant. I give as broad elements, that to the expression as a politician would give to the kindred one, “incidental and considerable.” By this he means to say that the assembly consists of representatives from the several constituencies, which is a distinct piece of information so far as it goes, and is a useful one, although it deals with no matter of detail. It is by thinking about the number of electors, their qualifications, or the manner in which they are influenced; it gives no information as to the number of seats; it does not tell how many candidates there are usually for each seat, nor whether the same person is eligible for, or may represent at the same time, more than one place, nor whether the result of the elections at one place may not influence those at another (on the principle of correlation). After these explanations the trust, he has no difficulty in accepting my definition of the general character of the relation between the embryonic and the structureless elements, the former are the result of election from the latter on some method of Class Representation.

The latent elements in the embryonic stage must be developed by a parallel, I do not say by an identical process, into those of the adult stage. Therefore, to avoid all chance of being misapprehended when I come later on to what they will call, in the diagram I am about to give, the one process “Development (a)” and the other “Development (b).”

It is not intended to affirm, in making these subdivisions, that the embryonic and adult stages are distinctly separated; they are certainly impossible but that they should overlap, some elements remaining embryonic while others are completely formed. Nevertheless the embryo, speaking broadly, may fairly be looked upon as consecutive.

Again, the two processes are not wholly distinct; on the contrary, they embryo, and even the adult in some degree, must receive supplementary contributions derived from their corresponding latent elements, because ancestral qualities indicated in early life frequently disappear and yield place to others. The reverse process is difficult; it may exist in the embryonic stage, but it certainly does not exist in a sensible degree in the adult stage, else the latter children of a union would resemble their parents more nearly than the earlier ones.

Lastly, I must guard myself against the objection, that though structure is largely correlated, I have treated it too much as consisting of separate elements. To this I answer, first, that in describing how the embryonic were derived from the structureless elements, I expressly left room for a small degree of correlation; secondly, that in the development of the adult elements of the embryonic, there is a perfectly open field for natural selection, which is the agency by which correlation is destroyed; and thirdly, that correlation affects groups of elements, and not the complete person, as is proved by the frequent occurrence of small groups of persistent peculiarities, which do not affect the rest of the organism, so far as we know, in any way whatever.

The ground we have already gained may be described as follows:—

Out of the structureless ovum the embryonic elements are taken by Class Representation, and these are developed (d) into the visible adult individual. On the other hand, returning to our starting-point at the structureless ovum, we find, after the embryonic elements have been segregated, the large residue is developed (b) into the latent elements contained in the adult individual. This is summarily expressed in the first two columns of the diagrams as the insetted vertical arrows to show the minor connections between the stages in the two parallel processes, but it would have complicated the figure.

In what way do the patent and latent adult elements respectively contribute representatives towards the structureless stage of the next generation? We know that every quality that possess may be transmitted to it, but it does not follow that they are invariably transmitted. The contributions from the patent elements cannot be by class, because their own original elements have been themselves specialised, and cannot contain no more than one or a few members of each class (which, it is true, must have been somewhat developed, both in numbers and variety). Their contributions may therefore be justly described as being effected on some principle that has resulted in a “Family representation,” though whether in a strictly universal representation I do not profess to say.

As regards the large variety of adult latent elements, they cannot all be transmitted, for the following obvious reason: the corresponding qualities of the two parents can be considered exactly alike; therefore the accumulation of the elements of if they were all preserved, as the generations rolled onwards, would exceed in multitude the widest flights of rational theory. The heritage of peculiarities through the contributions of 1,000 consecutive generations, even a great deal of ancestral intermarriage, must far exceed what could be packed into a single ovum. The contributions from the latent adult elements are therefore no more than representative; but we know they cannot be so on the broad principle of “class representation,” if the word “class” be applied to the same degree as before, and if the representatives are few in number, then it is incumbent on them to furnish all the various members of each class whence the representatives have to be drawn. Therefore, bearing in mind what has just been argued, that it is impossible for the elements of every individual quality of the two parents, we are driven to suppose, as in the previous case, a “Family Representation,” the similar elements contributed by the two parent ranking, of course, as of the same family. It is most important to bear in mind that this phrase states a fact and not an hypothesis; it does not mean that each and every family has just one representative, for it is absolutely reticent on all matters of detail, such as those I enumerated, when speaking of Class Representation.

To show the importance which I attach to this disclaimer, I may be permitted to mention what appears to me the probable mode of operation, namely, that it is in reality a large selection made on a broader and not a narrower system than that of classes, and similar to that obtained by an indiscriminate consumption; thus, if a large army be drawn from the provinces of a country by a general consumption, its constitution, according to the laws of chance, will reflect with the greatest precision the qualities of the population whence it was taken; each village will be found to furnish a contingent, and the composition of the army will be sensibly the same as it had been due to a system of immediate representation from the several villages.

The following diagram expresses the foregoing results:—It begins with the structureless elements, whence the parent individual was formed, and ends with its contributions to the structureless elements, whence its offspring is formed.

I will now inquire, what are, roughly speaking, the relative proportions of the contributions to the elements made respectively by the patent and latent elements of the adult parent? It is better not to complicate the inquiry by speaking, at first, of these elements in their entirety, but rather of some
special characteristic; thus, to fix the ideas, suppose we are speaking about a peculiar skin-mark in an animal. The peculiarity in question may be conceived (1) as purely personal, without the concurrence of any latent equivalents, (2) as personal but conjoined with latent equivalents, and (3) as exsistent wholly in a latent form. It can be shown that, in the first case, the power of hereditary transmission is exceedingly feeble, and notwithstanding some exceptions (as in the lost power of flight in domestic birds), the effects of the use and disuse of limbs, and those of habit, are transmitted to posterity in only a very slight degree. Again, it can be fairly argued that many classes of cases which seem at first sight to fall under case (1) are in reality to be purely personal, and to prove a larger hereditary influence than what I assign to it, do really belong to case (2). Thus, when individuals born with a peculiar mark are reputed to be the first of their race in which it had ever appeared, it would be hazardous in the extreme to argue that the latent element in the form did not exist, and that the manifestation is on the average, the produce of parents having the peculiarity not only in a personal, but also, to some degree, in a latent form. We may therefore reasonably conclude that, had the latter portion been non-existent, the ratio of successful cases would have been materially diminished.

I should demur on precisely the same grounds to objections based on the fact of the transmission of qualities to grandchildren being more frequent through children who possess those qualities than through children who do not; for I maintain that the personal manifestation is on the average, though it need not be so in every case, a certain proof of the existence of some latent elements.

Having proved how small is the power of hereditary transmission of the personal elements, we can easily show how large is the transmission of the purely latent elements, in the case (3) by appealing to the well-known facts of reversion; but into these it is hardly necessary for me to enter at length. The general and safe conclusion is that the contribution from the latent elements is very much less than from the latent ones.

If we now combine our results into a single diagram, showing the fainter stream of heredity by italic lines, and indicating those processes by asterisks (*) which were described at length in the previous figure, we shall easily recognise the complexity of hereditary problems. We see that parents are very indirectly

<table>
<thead>
<tr>
<th>Structureless elements of offspring</th>
</tr>
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<tr>
<td>through <em>Class-Representation</em> Embryonic elements which by <em>Development</em> contribute to</td>
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<td><em>Adult FATHER</em></td>
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<td><em>Adult MOTHER</em></td>
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<td>which by <em>Family-Representation</em> contribute to</td>
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<tr>
<td><em>Embryonic</em></td>
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<tr>
<td><em>Adult OFFSPRING.</em></td>
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</table>

and only partially related to their own children, and that there are two lines of connection between them, one of large and the other of small relative importance. The former is a collateral kinship and very distant, the parent being descended through two stages (two asterisks) from a structureless source, and the child (so far as the parent's character is concerned) through totally distinct stages from the same source. The other, but unimportant line of connection, is direct, and connects the child with the parent through two stages. We shall therefore wonder that notwithstanding the fact of an average resemblance between parent and child, the amount of individual variation should not be much greater than it is, until we have realised how complete must be the harmony between every variety and its environments, in order that the variety should be permanent.

We also infer from the diagram how near, and yet how subject to variation, is the kinship between the children of the same parents; for only two stages are required to trace back their descent to a common origin, which, however, proceeds from four separate streams of heredity, namely, the adult patent and latent elements of each of the two parents.

An approximate notion of the nearest conceivable relationship between a parent and his child may be gained by supposing an urn containing a great number of balls, marked in various ways, and a handful to be drawn out of them at random as a sample. This sample would represent the person of a parent. Let us now suppose the same urn to be examined, and a handful of new balls to be marked according to the patterns of those found in the sample, and to be thrown along with them back into the urn. Now let the contents of another urn, representing the influences of the other parent, to be mixed with those of the first. Lastly, suppose a second sample to be drawn out of the combined contents of the two urns, to represent the offspring. There can be no nearer connection justly conceived to subsist between the parent and child than between the two samples; on the contrary, my diagram shows the relationship to be in reality much more remote, and consisting of many consecutive stages, and therefore hardly to be expressed by such simple chances. Whenever the balls in the urns are much of the same pattern, the samples will be alike, but not otherwise. The offspring of a mongrel stock usually deviate in appearance from each other and from their parents.

We cannot now fail to be impressed with the fallacy of reckoning inheritance in the usual way, from parents to offspring, using those words in their popular sense of visible personalities. The correct true hereditary link connects, as I have already insisted upon, not the parent with the offspring, but the primary elements of the two, such as they existed in the newly impregnated ovum; whereas they were respectively developed. No valid excuse can be offered for not attending to this fact, on the ground of our ignorance of the variety and proportionate values of the primary elements. We do not need matters in the least, but we gratuitiously add confusion to our ignorance, by dealing with hereditary facts on the plan of ordinary pedigrees—namely, from the parents of the parents to those of their offspring.

It will be observed that, owing to the clearer idea we have now obtained of the meaning of kinship and of the consecutive phases of the chain of life, the various causes of individual variation can be easily and surely sorted into their proper places. I will mention a few of them, merely as examples.

In the segregation of the embryonic elements, if the structure-
less ones be diverse without any strongly preponderating element, it is impossible to foresee the character of the embryo, just as it is impossible to foresee the character of a handful chosen from an urn containing a mixed assemblage of variously coloured balls. But if they be not diverse, then the embryonic elements will be a true sample of the structureless ones, the conditions of purity of blood are fulfilled, and the offspring will resemble its parents.

We also see, in the process by which the embryonic elements are obtained, how the curious phenomenon may occur and is occasionally skipping alternate generations. The more that has been removed from the structureless group for the supply of the embryonic (which as we have seen, in a nearly sterile destination) the less remains for the latent group, too little, it may be, to express itself by that, the only probable, line of transmission, in the supposed case it would recuperate itself during the succeeding generation, where the elements in question will have remained wholly latent, owing to their insignificance in the structureless stage of that generation, which would be sufficient to secure any portion of it thru transmitted by inheritance.

It is in the stage of development where I presume those influences to come in, which cause domesticated animals, when turned loose, to become feral. No variety can be stable unless the conditions of development concur to maintain the structureless stages of consecutive generations in an unchanged form. It is clearly of no avail to a breeder to obtain a stock by continued and careful selection, that shall conform to a desired type, if the animals be afterwards reared under other conditions, by which the subsequent stages, both latent and patent, shall be modified.

Lastly, it is in the process of selection of elements, both latent and patent, from the adult parents for the structureless stage of the next generation, where I suppose the curious and unknown conditions usually to occur, through which a change in the habits of life, after the age of puberty has been reached, is apt to produce sterility. I may be permitted to remark, hypothetically, that this view appears to be corroborated by the fact, that many grains of pollen or many spermatzoa are required to fertilize each ovum, because, as it would seem, each separate one does not necessarily complete representation of the germ elements to supply the needs of an individual life, and that it is only by the accumulation of several separate consignments (so to speak) of the representative elements, that the necessary variety is ensured. I argue from this that there is a tendency to a large individual variation in the constitutions of each grain of pollen or spermatzoa, and, by analogy, that there is a similar though smaller tendency in each ovum. Also, that changes in the habits of life may increase this variation to a degree that involves sterility.

One result of this investigation is to show very clearly that large variation in individuals from their parents is not incompatible with the strict doctrine of heredity, but is a consequence of it wherever the breed is impure. I am desirous of applying these considerations to the intellectual and moral gifts of the human race, which is more monopolised than that of any other domesticated animal. It has been thought by some that the fact of children frequently showing marked individual variation in ability from that of their parents, is a proof that intellectual and moral gifts are not hereditary. The arguments lead to exactly the opposite result. I show that their great individual variation is a necessity under present conditions, and I maintain that results derived from large averages are all that can be required, and all we could expect to obtain, to prove that intellectual and moral gifts are as strictly matters of inheritance as any purely physical qualities.

SOCIETIES AND ACADEMIES

LONDON

Chemical Society, June 20.—Dr. Frankland, F.R.S., president, in the chair. The president announced that Mr. Hyde Hills had given ten guineas to the fund for promoting original research, and proposed to further increase the donation by ten guineas for each paper published in the same. Mr. H. D. Humphry, F.R.S., in a paper, entitled "Deacon's Method of Obtaining Chlorine, and Illustrating some Principles of Chemical Dynamics," the process consists in passing a heated mixture of air and hydrochloric acid over sulphate of copper, or over pieces of pumice or brick saturated with the same. He finds that the action is essentially a surface action, and that there is a certain comparatively small range of temperature, between the critical limits of which the percentage of hydrochloric acid decomposed varies greatly. The velocity with which the mixed gases pass over the surface of the active material also causes considerable variation in the comparative amount of chlorine produced.

BOOKS RECEIVED


PAMPHLETS RECEIVED


THE THEATRE


DIARY

THURSDAY, June 27.


FRIDAY, June 28.

QUERRY'S MICROSOPHICAL CLUB, at 8.

MONDAY, July 1.

ENTOMOLOGICAL SOCIETY, at 8.

TUESDAY, July 2.

SOCIETY OF BIBLICAL ARCHAEOLOGY, at 5: On Israel in Egypt: Dr. H. E. Brow.—On the Book of Nehemiah: Rev. G. E. Moore, F.R.S.


CONTENTS

Page

The Use and the Treasury. 3

Public Health in America. 137

Our Book Shelf. 159

LETTERS TO THE EDITOR

The Total Eclipse in Java. Prof. Oudemans. 150

The Great Storm of June 18 (With Diagram). Dr. C. M. Ingleby. 151

Symposium of Lichinomy. H. R. Proctor. 155

Water Analysis. J. Alfred Wanklyn. 156

Parasite of the Beaver. J. La Conte. 156

Verneuil.—P. E. Porter. 156

Origin of Cyclones. J. M. Murphy, F.G.S. 156

The Exploration of the Philippine Islands. By Dr. A. Bernhard Mayer. 162

Mineral Springs of Shona near Tiberiondo. By W. Gibb. 163

The Dispersion of Smoke by the Wind. 164

Litch's Principles of Geology (With Illustrations). T. McK. Hughes, F.G.S. 164

Notes. 165

Atoms and Molecules. By Samuel B. Tilling, Ld. D.

Blood Relationship. By Francis Galton, F.R.S. 173

Societies and Academies. 176

Bromides and Pamphelets Received. 176

DIARY. 176

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