

way account for the conditions presented by the higher plants.

The existence of dicecious races with a widely varying percentage of the sexes is also against the assumption that sex is transmitted as a Mendelian character. Heyer found the hemp plants about Halle showed a ratio of 100 males to 114 females. Fisch at Erlangen found the ratio was 100 males to 154 females.

The conditions noted as to the stage at which sex differentiation occurs, etc., suggest at least the universal presence in plant cells of the potentiality for development in the direction of either sex when the necessary environmental conditions are given.

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#### SEX-DETERMINING FACTORS IN ANIMALS

THERE are few biological questions that appeal more directly to the human race than whether the sex of the child can be determined by the external conditions under which the parents live, or whether the conditions are internal and, therefore, beyond the power of control. This problem has been examined by the statistician, argued by philosophers, discussed by the naturalists and exploited by the quack. Theories of sex determination have flourished like weeds, and, while perennial, are apt to be like their prototypes, short lived. The history of these theories is, nevertheless, full of interest and not without significance. Even a brief survey will bring out the salient points.

Aristotle refuted the opinion of Anaxagoras that the male comes from the right side and the female from the left side of the father; that of Empedocles, who held that the temperature of the uterus influences the sex of the offspring; and that of Democritus, who suggested that the excess of the male or of the female element is the essential factor. Aristotle, in turn, held

that the temperature of the germ-material determines the sex, for, he said, more males are born to young and to old parents than to those of middle life, because in youth the temperature of the body has not reached its maximum and in old age it has begun to abate. In recent years we find that one external factor above all others has been supposed to have an intimate relation to sex determination, namely, nutrition. An experiment of Landois in 1867 furnished the first erroneous evidence in favor of this view. He claimed that he could produce at will males or females of the butterfly *Vanessa* by regulating the amount of food. A similar conclusion was reached by Mrs. Treat and by Gentry in 1873. Riley, Bessels, Briggs, Andrews, Fletcher, and Kellogg and Bell have shown that no effects of this kind are produced by starving or by feeding. At most there occurs a greater mortality of the female caterpillars through starvation, leaving more males alive. The futility of the experiment is now manifest, since it has been shown that the reproductive organs of the male and female are already laid down when the caterpillar leaves the egg.

Equally inconclusive have been the experiments with the tadpole of the frog. The work of Born and of Yung has been upset by the experiments of Pflüger, Cuénot and of Richard Hertwig. The earlier observers failed to take into account the great mortality of the tadpoles kept under artificial conditions, hence a possible source of error is present in their results, and the conclusions are unsatisfactory so long as we do not know whether in the frog one sex is more susceptible than the other to unfavorable conditions. Aside from this possibility there seems to be something very peculiar about the proportions of the sexes in these amphibians.

Düsing has applied the statistical method of study to the proportion of males and

females in the human race, and has reached the conclusion that the nutrition of the parents is an important factor in sex determination. His conclusion may be seriously questioned, because other statistics have given contradictory results (those of Punnett, for example), and because it is apparent that so many other external factors than food may be involved that the slight difference on which Düsing based his conclusion may be due to other conditions than nutrition. If, in reality, nutrition were a factor in sex determination in man we should expect to find, I think, a far greater disproportion of males to females in the offspring of the rich and of the poor than Düsing's statistics show. If further evidence is needed it is furnished by the recent experiments of Cuénot with rats, and of Schultze with mice. Even extreme conditions of starvation and of feeding produced no effects upon the birth rate of males to females.

If there were time we might pass in review the other external factors that have been supposed to account for sex determination. It must suffice to state that in no instance has a good case been made out for any one of them.

Our opinion in regard to the possible effects of external factors in sex determination has been influenced by our knowledge of the changes that take place in the life cycle of certain animals—changes that appear at first sight to be associated with sex, but in reality may relate to another phenomenon. In two, possibly in three, groups of animals a change from the parthenogenetic to the sexual mode of reproduction appears to be associated with changes in the environment. I may mention first the aphids, since I have studied the problem in this group. As is well known, parthenogenesis is the rule during the summer, but in the autumn the sexual forms appear. Cold

does not bring about the result and it is almost certain that the change is incited by food conditions. The important fact to note is that, although an external factor causes the appearance of the males, it does so by introducing a new method of reproduction in which *both* males and sexual females appear.

A somewhat similar result has been found in *Daphnia*, where, also, according to the recent results of Issakowitsch, lack of food causes parthenogenetic reproduction to cease, and *both* males and sexual eggs to appear.

For the rotifer, *Hydatina senta*, Maupas has claimed that temperature regulates sex, while Nussbaum has tried to show that food is responsible for the result. Quite recently Punnett has discovered that the determining condition is not external at all, but that there are male strains and female strains, that give rise to their particular sex independently of the environment.

In the light of the evidence that we have at present it seems probable then that, in the higher animals at least, sex is determined by internal, not by external, factors. What the nature of the internal mechanism may be we do not know, but it is a curious and significant fact that in modern attempts to account for the nature of the change that takes place, the biologist finds himself trying once more to steer his course between the inevitable alternatives of preformation and epigenesis. The history of our science has shown, in fact, that preformation and epigenesis are two poles of thought between which speculation continually and necessarily vacillates.

One school, the preformationists, assumes that only the male or the female characters are carried by each egg or sperm, hence sex is preformed in the sense that its primordia are separated and come to lie in different germ cells.

The opposite school, that of epigenesis,

assumes that all eggs and every sperm carry the potentialities of both sexes; there are no male and no female eggs, no male or female sperm, in the sense that each carries only one set of characters, but every germ cell is a sex-hybrid, and the fertilized egg is a double-barreled sex-hybrid. This view maintains that the sex of the embryo is determined by an internal condition that is present in the egg or sperm, which leads to the domination of one of the two possible alternatives. This is modern epigenesis as I understand it; predetermination, perhaps, but not preformation through the separation of contrasted characters. From this point of view we can imagine that sex-determination may be reached in more than one way. It may be due to conditions that are present in the sperm or in the egg, or as a result of the union of egg and sperm, for any internal, or even external, condition, that turns the balance one way or the other is a sex determinant.

It now appears probable that the problem of sex determination is to be sought in the same mechanism that accounts for alternative inheritance in general, Mendelian or otherwise. Strasburger, Bateson and Castle have pointed out the close parallel that seems to exist between the two cases. In Mendelian inheritance also we have to face the alternatives of preformation and epigenesis. The currently accepted interpretation of Mendelian inheritance is strictly one of preformation. Alternative characters are treated as entities in the germ cells that may be shuffled, but seldom get mixed. With each new deal the characters are separated, one germ cell getting one character and another the contrasted character.

If we take the opposite point of view, that of epigenetic development, the outcome, wherever alternative or contrasted characters are involved, is not due to separation, but to alternative dominance and

recession, which need not give three types, but only two, if selective fertilization occurs, or, if only the egg or the sperm contains the internal factor that determines, that one or the other of the alternative sex characters shall predominate.

Which of these general points of view, preformation or epigenesis, we may think more profitable as a working hypothesis is, I believe, the question of the hour. My own preference—or prejudice, perhaps—is for the epigenetic interpretation, but the whole truth may lie somewhere between these two forms of thought that are the *Seylla* and *Charybdis* of biological speculation.

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#### SCIENTIFIC BOOKS

*Abhandlungen ueber theoretische Physik.*

Von H. A. LORENTZ. Leipsic, B. G. Teubner. 1906.

This work of Professor Lorentz is the result of a request of the publishers asking that a new edition of his articles on theoretical physics be prepared. The first part of the first volume appeared in 1906, and the complete work will consist of two volumes. The titles of the chapters in the first part of the first volume will be given below, together with some remarks indicating the nature and scope of the work.

Chapter I.—Some Considerations on the Principles of Dynamics in connection with Hertz's 'Prinzipien der Mechanik.' Starting with the principle upon which Hertz causes the whole science of dynamics to rest, viz., that a material system moves with constant velocity in a path of least curvature, Professor Lorentz investigates the question as to how far the method of Hertz is advantageous if one disregards Hertz's hypotheses concerning hidden motions and considers the system under the action of forces in the usual sense of the word.

After presenting in his own clear and concise way the fundamental notions of Hertz, the author shows how they lead to the general