

CHAPTER I

THE PROBLEM

THE question "Is it a boy or a girl?" is perhaps the first which is generally asked about the majority of mankind during the earliest hours of their independent existence; and the query "Will it be a boy or a girl?" must equally often be in the mind, even if it is less frequently expressed in words. This second question raises one of the most widely discussed problems of biology, that of the causes which determine whether any individual shall be male or female, and it suggests the still deeper question, "Why should there be male and female at all?" The problem of the nature and cause of Sex ranks in interest with that of the nature and origin of Life, and it may be that neither can be completely solved apart from the other. Notwithstanding the immense amount of brilliant speculation and research which has been devoted to the fundamental problem of Life, it must be admitted that hitherto no satisfactory solution has been found, and in some respects the question of Sex is equally obscure. Hardly any other problem has aroused so much speculation, and about few has there been such great divergence of opinion. In one direction, however, the last few

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years have seen a considerable advance, and we now know at least something of the causes which lead to the production of one or the other sex, although of the manner in which these causes act our ignorance is still profound.

It is but a short step from the question “ Is it a boy or a girl ? ” to the further question “ Why is it a girl instead of a boy ? ” and yet until recently the answer to the second question seemed hopelessly beyond our grasp, and even now, although some indications of an answer can be given, they do not touch the deeper problems of the real nature of sex. It is a remarkable thing that apart from the fundamental attributes of living matter—irritability, assimilation, growth and so forth—no single character is so widely distributed as sex ; it occurs in some form in every large group of animals and plants, from the highest to the lowest, and yet of its true nature and meaning we have hardly a suspicion. Other widely distributed characters have obvious functions ; of the real function of sex we know nothing, and in the rare cases where it seems to have disappeared, the organism thrives to all appearance just as well without it. And in many other cases, especially in plants, where sex is definitely present, it may apparently be almost or quite functionless, as, for example, in the considerable number of plants which are habitually grown from grafts or cuttings, and in which fertile seeds are never set. It is of course impossible to say with confidence that such “ asexual ” reproduction can go on quite indefinitely, but the evidence formerly adduced that continued vegetative reproduction leads

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to degeneration has been shown to be of doubtful validity. Sex, therefore, although it is almost universally found, cannot be said with certainty to be a necessary attribute of living things, and its real nature remains an apparently impenetrable mystery. A further problem, related to the last, arises from hermaphroditism—the presence of both sexes in one and the same individual. In the lower animals and many groups of plants this condition is frequently found, but its occurrence is quite irregular ; it may be characteristic of large groups in some cases, of isolated species or even of individuals in others. It has sometimes been supposed that the hermaphrodite condition is primitive, and that the separation of the sexes into different individuals is a higher stage of evolution, but the evidence tends on the whole to show that the converse is true, and that hermaphrodite species have usually been derived from ancestors with separate sexes. The deeper problems of sex are still far beyond our comprehension, and up to the present time only one clear line of advance towards their solution has appeared, that of discovering, if possible, how the sex of the individual is determined. It is to this small branch of the subject that the present volume is devoted.

Before proceeding further, it may be well to explain more definitely what is meant by “the determination of sex.” Popularly it is often supposed to mean the production of one or the other sex at will, but this is not the sense in which the phrase is used in biology. The study of the determination of sex is the study of the causes which lead

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to the production of an individual of one or the other sex, and those causes, when discovered, may or may not be amenable to human control. We may discover the causes of storms or earthquakes, and when our knowledge of them is sufficiently advanced we may perhaps be able to predict them as successfully as astronomers predict eclipses, but there is little hope that we shall ever be able to control them. So it may be with sex; a complete understanding of the causes which determine it may not necessarily give us the power of producing one or the other sex at will, or even of predicting the sex in any given case. Whether we shall ever be able to influence the causes of sex-determination cannot as yet be foretold; at present biologists are engaged in the less practical, but immensely interesting, problem, of discovering what those causes are. One other source of possible misunderstanding must also be referred to, that of the use of the word "cause" in connexion with sex-determination. If one condition is found to be followed invariably by a second, the first is called the (or a) cause of the second, but it does not follow that the one is the only or immediate cause of the other. The presence of a factor *A* may invariably be followed by condition *E*, but it may happen that *A* acts by setting up the chain of events *B*, *C*, *D*, and that any of these, if produced by a different "cause" would in turn lead to *E*. Hence, for example, it must not be assumed without further investigation that if the presence of a body *A* in an egg is always followed by the development of

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Plate I

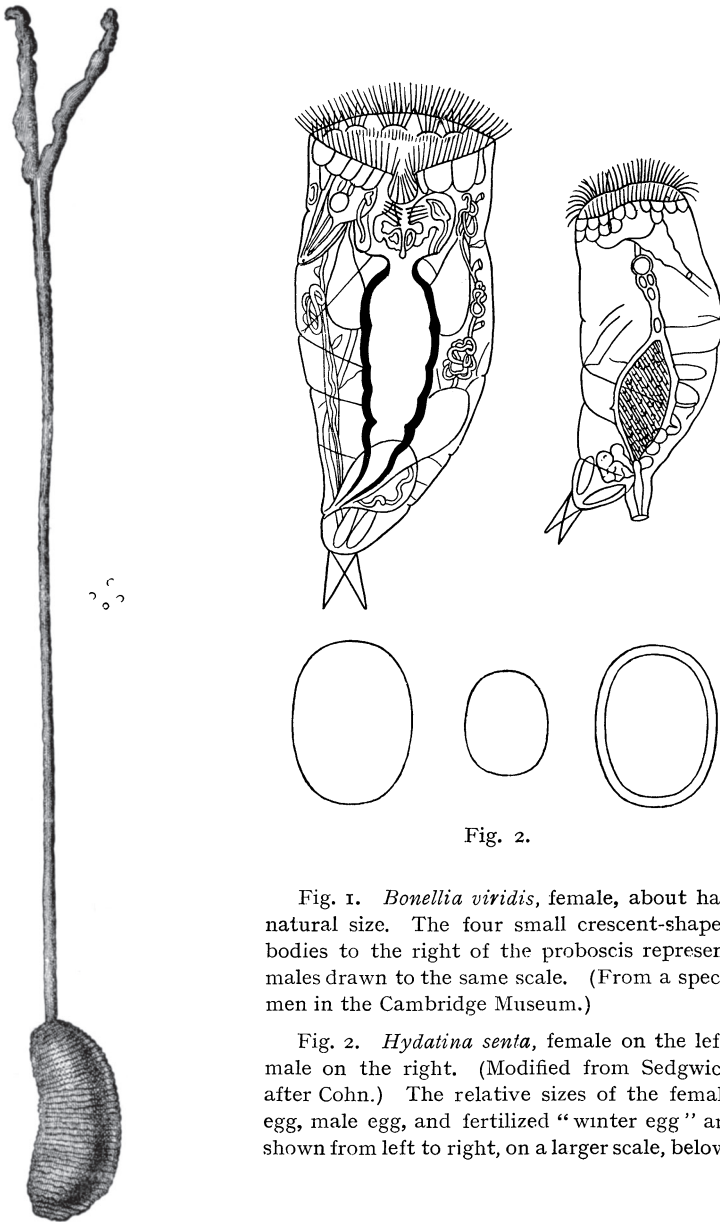


Fig. 1.

Fig. 2.

Fig. 1. *Bonellia viridis*, female, about half natural size. The four small crescent-shaped bodies to the right of the proboscis represent males drawn to the same scale. (From a specimen in the Cambridge Museum.)

Fig. 2. *Hydatina senta*, female on the left, male on the right. (Modified from Sedgwick after Cohn.) The relative sizes of the female egg, male egg, and fertilized "winter egg" are shown from left to right, on a larger scale, below.

that egg into a female, therefore all females are derived from eggs which contain *A*. They very probably may be, but that they are must be shown by independent proof.

With this introduction we may proceed to state the problem before us. Put shortly, it is to find explanations for the following facts. In the great majority of animals, and in many plants, every individual is either male or female. In each species there is a fairly constant average ratio between the number of males and females born; this ratio is commonly not far from equality, but varies considerably from species to species. In most animals and in some plants the difference between male and female does not concern only the organs directly connected with reproduction, but affects various parts of the body to a greater or less degree, so that the sexes are more or less readily recognisable by so-called "secondary sexual characters," such as the antlers of deer or the beard of man. Not rarely the differences are very striking, as in the peacock among birds, and finally we get the most extreme cases of "sexual dimorphism," as in the marine worm *Bonellia* (Plate I, fig. 1), in which the male is an almost microscopic parasite living in the body of the female, or in moths of the family *Psychidae*, and in some foreign species of *Orgyia*, in which the female is so degenerate as to be unable to leave the cocoon. These facts—the existence of two distinct sexes, the comparative regularity of the ratio in which they are produced, and the development of secondary sexual characters—are

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perhaps the most important branches of the subject, but they do not by any means exhaust the problems connected with the determination of sex. Hermaphroditism has already been mentioned, and it is obvious that any complete account of sex-determination must include an explanation of its cause. Another phenomenon which has very important bearings on the subject is Parthenogenesis, the production of offspring from eggs which have not been fertilized. Since in some cases such parthenogenetic eggs constantly give rise to males, in others to females, and in others again to either sex, it must be expected that valuable suggestions with regard to the mechanism of sex-determination should be obtained from a study of their behaviour. Finally, the relations between sex and heredity have given some of the most important clues, for if an animal transmits certain characters only to one sex among its offspring, it follows that the mechanism of sex-determination must be connected in some way with that of hereditary transmission.

These, then, are the chief problems which must be discussed, but it must be made clear at once that they are not all by any means solved at the present time. Our progress in the last few years has been rapid, but new difficulties appear as the old ones are removed, and a final answer can be given to hardly any of the questions raised. The purpose of this book is thus to show the present state of our knowledge, and to indicate the directions in which it seems that answers must be sought, rather than to set forth a completed theory of sex-determination.

CHAPTER II

THE NATURE AND FUNCTION OF SEX

AN obvious preliminary to a discussion of sex-determination is a fairly clear idea of what is meant by the word Sex. In forms of life as various as mankind, birds, or insects, even in such trees as the willow and such Protozoa as *Vorticella*, we speak of some individuals as being male, and of others of the same species as being female. What is there in common between a hen and a willow-tree bearing green catkins that should justify our calling them female, while we say that the cock and the willow with yellow catkins are males? In the case of animals, a female may generally be defined as an individual which is capable of producing eggs, whether they are laid before development begins or whether the young develop to a greater or less extent before they are born. And it is no mere metaphor to describe a tree or plant, or a particular flower or part of a flower, as female, if it is a plant or part which bears seeds, for a seed is an embryo plant contained within an investing coat, just as an egg which has been incubated is an embryo chick within a shell. The fundamental thing, then, about the female sex is that female individuals produce bodies known as *egg-cells* or *ova*, which after uniting

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with a cell of a different character derived from the male, develop into new individuals. Superficially, egg-cells vary greatly in appearance; they may be relatively large, owing to the inclusion of nourishing substance or yolk for the developing embryo, or they may be microscopic, as they generally are when no yolk is present. They may have a special protective covering, or may be naked, but apart from these differences, which are so to speak accidental, they are always characterized, in the most various animals and plants, by consisting of a mass of relatively unmodified protoplasm containing a single nucleus¹.

As the distinguishing character of the female is the production of eggs or ova, so that of the male is the production of male germ-cells, which, however, vary greatly in different cases. They are characterized by the fact that their function is to reach an ovum and unite with it in the process of *fertilization*, as will be described in more detail below. In nearly all animals and in many of the lower plants, the male germ-cells are for this purpose endowed with the power of independent locomotion; in animals they are called *spermatozoa* (in the singular, spermatozoon, sometimes abbreviated to sperm) and in the lower plants *spermatozoids*. In the flowering plants the male germ-cells are enclosed in the

¹ Protoplasm is the name given to the substance which is the material basis of all living things. In chemical constitution it resembles white-of-egg, and consists of very complex compounds of carbon, hydrogen, oxygen and nitrogen, with a smaller amount of sulphur, phosphorus, and other mineral elements. Some account of the nucleus will be given below.