

**Further Remarks on the Cell-theory, with a
Reply to Mr. Bourne.**

By

Adam Sedgwick, F.R.S.

IN a paper published last autumn (this Journal, vol. 37), I called attention to the apparent inadequacy of the cell-theory. Recently a criticism upon my article has appeared from the pen of Mr. G. C. Bourne, to which I may be allowed to devote a few words. But before replying to Mr. Bourne, I should like to state my position with regard to the theory a little more fully than I have hitherto done. In my previous communication I used the word "inadequacy" because it seemed to me to express, as nearly as possible, my own views with regard to the theory. A theory to be of any value must explain the whole body of facts with which it deals. If it falls short of this, it must be held to be insufficient or inadequate; and when at the same time it is so masterful as to compel men to look at nature through its eyes, and to twist stubborn and uncomformable facts into accord with its dogmas, then it becomes an instrument of mischief, and deserves condemnation, if only of the mild kind implied by the term inadequate.

The assertion that organisms present a constitution which may be described as cellular is not a theory at all; it is—having first agreed as to the meaning and use of the word cell—a statement of fact, and no more a theory than is the assertion that sunlight is composed of all the colours of the spectrum. The theory comes in when we try to account for the cellular constitution of organisms; and it is this theoretical part of the cell-theory, and the point of view it makes many of us assume, that I condemn. It is not the word "cell" which

I am at issue with, for structures most conveniently called cells undoubtedly exist, as the ovum, spermatozoon, lymph-cells, &c. ; and I fully agree that the phenomenon called cell-formation is very general in organic life. But at the same time I hold with Sachs and many others that it is not of primary significance, but "merely one of the numerous expressions of the formative forces which reside in all matter." No one who has studied animal tissues could for one moment deny that nuclei have in many cases a relation to the surrounding protoplasm, a relation which is expressed in the arrangement and structure of that protoplasm. They have not always this relation, but it is usually present, and the question is, how are we to interpret it? That we cannot interpret it finally until we know the relative values of nucleus and extra-nuclear protoplasm, and the functional relation between the two, is clear; but we may form and hold provisional theories. The hypothesis or idea which holds the field at the present day is the cell-theory in its modern form. This theory, recognising the cellular structure (while not admiring the phrase, I must use it for want of a better one) asserts that organisms of Metazoa are aggregations or colonies of individuals called cells, and derived from a single primitive individual—the ovum—by successive cell-divisions; that the meaning of this mode of origin is given by the evolution theory, which allows us to suppose that the ancestor of all Metazoa was a unicellular Protozoon, and that the development of the higher animals is a recapitulation of the development of the race. Thus the holoblastic cleavage of the ovum represents the process by which the ancestral Protozoon became multicellular, and the differentiation of the cells into groups the beginning of cellular differentiation. According to this view the order is: unicellular stage—multicellular stage—differentiation of cells into tissue elements; cellular structure preceded cell-differentiation, and to get tissues you must first have cells. And ten years ago it was commonly held that these cells were primitively separate from one another, and that the connections found between them in the fully

formed tissues were secondary. You had your neuro-epithelial cell, and your musculo-epithelial cell, each derived from a distinct cell produced by division of the ovum; and the question was, how do they find each other and become connected?¹ Further, in studying the development of a tissue you had to find a group of cells, each of which became modified into one tissue element. Thus the primitive streak was a proliferating mass of cells which eventually gave rise to a number of mesodermal tissues; the nerve-crest similarly was a mass of cells which gave rise to nervous tissues; a nerve-fibre was one of these cells elongated, and before you would get your nerve-cell and fibre you must have your nerve-crest cell produced by division from the cells of the nerve-cord, and subsequently sending out a process which elongated and travelled to the periphery as a nerve-fibre.

My work on *Peripatus* first led me to doubt the validity of this view of the origin of the Metazoon body. In the first place I found that in some forms there is no complete division of the ovum, and on examining the facts I discovered that such forms were more numerous than had been supposed. It therefore appeared that in some Metazoa the ovum divided into completely separate cells, while in others it did not so divide. The question then arose, which of these methods is primitive? and the answer naturally was, the complete division, because this fitted in with our ideas as to the supposed evolution of the Metazoa from a colonial Protozoon. But on reflection this difficulty arose: the individuals of colonial Protozoa are in protoplasmic connection, while the cells of the completely segmenting ova are separate; so that the parallel between the ontogeny and the phylogeny breaks down in an important particular. To get over this difficulty it was necessary to suppose that the isolation of the segments of incompletely segmenting ova was apparent and not real, that they were really connected by protoplasmic strands which had

¹ For exposition of this view vide Flemming, 'Zell-Substanz, Kern u. Zell-Theilung,' Leipzig, 1882, p. 74, and Balfour's Address to the Department of Anatomy and Physiology at the British Association in 1880.

escaped observation. But, on the other hand, there was the possibility that the completely segmenting ova were secondary acquisitions of ontogeny, and that the development in such forms as *Peripatus*, *Alcyonaria*, &c., was more primitive, and that the passage from a Protozoon to a Metazoon had taken place by way of a form more resembling a multinucleated ciliated Infusorian than *Volvox*. In other words, that the differentiation of the Metazoa had been effected in a continuous multinucleated plasmatic mass, and that the cellular structure had arisen by the special arrangement of the nuclei in reference to the structural changes. This was the stage to which my researches on *Peripatus* led me. Since then I have paid attention to Vertebrata, and I have found that a number of embryonic processes have been wrongly described, amongst them such important matters as the development of nerves and the origin of the mesoderm; and I thought that I traced the errors referred to to the dominating influence of the cell-theory in its modern form, for the facts seemed so obvious in themselves that it would have been impossible to make any mistake about them had they been examined without the prejudice imparted by a preconceived theory. A theory which led to such obvious errors must, I thought, be wrong, and I denounced it. But my denunciation in no way implies that I fail to recognise the so-called cellular structure of organisms or their origin from the one-celled ovum. On the contrary, I was led to a re-consideration of the question, what is the meaning of the predominance of the structure called cellular, which is characterised by a definite relation of the nuclei to the functional tissues, and of the fact that the organism so often passes through a unicellular stage. With regard to the former I must say that I have arrived at no conclusions which enable me to formulate to myself any satisfactory hypothesis, and, as I stated at the outset, I do not think it is possible to do this until we acquire some more understanding of the relative function of nuclei and protoplasm. But with regard to the latter there are some facts which might well be considered. In the first place, the unicellular origin

is only found in sexual reproduction, not in asexual. The characteristic of the unicellular form is its simplicity of structure, and the essential feature of sexual reproduction is the conjugation of the reproductive cells. Now in the Protozoa, in which the amount of formed tissue is generally slight and the structure of the body simple, conjugation can and does often take place between the ordinary form of the species. But in the Metazoa, in which conjugation is as necessary a phenomenon in the specific cycle as in Protozoa, conjugation is impossible between adult or ordinary individuals of a species from mechanical causes. How is this difficulty got over in nature? My answer is, by the formation of special individuals of extremely simple structure—a structure so simple that conjugation between them is possible. To put the matter in another way, I should regard the ordinary dioecious Metazoon as a tetramorphic species, consisting of male, female, ovum, and spermatozoon, the two latter being individuals which are specially produced to enable conjugation to take place.

Mr. Bourne, in his criticism, begins by complaining that he cannot ascertain from my article my own views on the subject of the cell-theory. Why should he expect or wish to discover them? My remarks were simply directed to show the shortcomings of the theory with regard to certain anatomical facts. As explained above, my own view is that the cell-theory is inadequate to explain the facts, and that it is not possible at present to explain them by any theory. He proceeds to state that I am abusive because I say that certain observers "are constrained by this theory with which their minds are saturated, not only to see things which do not exist, but also to figure them" (I am referring to embryonic mesoderm of vertebrates). He calls this abuse, not argument. I venture to differ with him—it is neither abuse nor argument; it is merely a statement of fact (unless, indeed, it be considered abusive to say that a man accepts and believes in the cell-theory). If you disbelieve it, consult the memoirs of the last twenty years in which this tissue is referred to, and in most of them you