THE CILIATE MACRONUCLEUS

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IT is now fairly clear that so far as staining reactions are an indication, the ciliate macronucleus contains a large amount of desoxyribose nucleic acid.[1] This is a matter of major significance, for it has been known for a long time that no chromosomes are formed in it during division, which is of the amitotic type. The occurrence, therefore, of a large quantity of desoxyribose nucleic acid in a nucleus which admittedly does not form chromosomes deserves an explanation; for in other organisms, this has been seen to occur only in association with the chromosomes.

Chromosomes have, however, been reported to be formed in the macronucleus of *Tetrahymena geleii* by Painter[2] and earlier by Hegner and Holmes[3] in *Balantidium*. But these would appear to be exceptions; for normally the division of the ciliate macronucleus is by the direct amitotic type, without chromosome formation. In species of *Epistylis* with which the authors are particularly well acquainted, it is indisputably so.

The occurrence of desoxyribose nucleic acid in the ciliate macronucleus leads one to conclude that it exists there in a condition and relationship very different from those in which it is present in the metazoan nucleus. Recent work[4] on the behaviour of the nucleus in mitosis has shown that the polymerization of the nucleotides is dependent on the protein framework of the chromosome. In fact, the chromosome thread (protein) controls the polymerization of its thymonucleic acid charge, and if the chromosomes are not formed in the ciliate macronucleus, it is more than likely that the reason lies in the extent or nature of its protein content. This in turn is related with the reproduction of the thread, and so the division of the nucleus itself. It is clear, therefore, that the whole chain of events and reactions of mitosis hinge on this central fact of the protein content of the nucleus; and if, in spite of the presence of one of the essential constituents of the chromosome, *i.e.*, desoxyribose nucleic acid, the chromosomes are not formed by the macronucleus, it is clear that the other constituent, *i.e.*, protein, is in some way deficient. In fact, one is led to the possibility of visualising the ciliate macronucleus as a body which is either partially or completely lacking in protein, and that that is responsible for the non-formation of the chromosomes by it, and in turn, for its amitotic division.

If it is true that the desoxyribose nucleotides occur in the macronucleus in an unpolymerized condition and unrelated to protein, then this would offer the first instance, unique among animals, where desoxyribose nucleic acid exists outside of and dissociated from the chromosome thread. But it is also significant that almost alone among normal nuclei of animals, the macronucleus of the ciliate is the one that unquestionably divides by amitosis.

The growth and reproduction of the macronucleus offer other interesting points. Whatever the condition in *Tetrahymena*,[2] the macronucleus of most ciliates, and particularly of *Epistylis*, divides at every binary fission, by a simple process of constriction, and each daughter individual has a macronucleus much smaller than that of the parent. This means, a period of growth must follow binary fission during which the macronucleus must enlarge. Growth of the macronucleus must involve the addition of material to it, which we have seen, is largely desoxyribose nucleic acid. It can come from one of two sources. The existing nucleotides in the macronucleus of the daughter individual must reproduce; or new nucleotides, manufactured in the cytoplasm, must find their entry into the nucleus through the nuclear membrane. In the one case it would be a multiplication of desoxyribose nucleotides within the nuclear membrane; in the other, the ribose nucleotides, manufactured in the cytoplasm, must get converted into those of the desoxyribose type on their entry into the nucleus.

If the former possibility is admitted, it will provide the first instance of the multiplication of desoxyribose nucleotides outside the protein medium of the chromosome, where only they are known to do so. This, however, is not surprising, for nucleic acid has been shown[5] to possess the inherent property of self-multiplication.

The second possibility is full of interest. That cytoplasmic nucleotides occur in a variety of animal cells is now fairly well known. That they contribute to the nucleic acid content of the chromosome at mitosis is also clear, and evidences have been presented for a transference of cytoplasmic nucleotides into the nucleus at every mitotic cycle, through the nuclear membrane during early prophase, and more especially at pro-metaphase, when by the breaking down of the nuclear membrane, the cytoplasmic and nuclear materials are in confluence. So it is not surprising that ribose nucleotides pass after every binary fission into the macronucleus, become converted into those of the desoxyribose type and so augment the nucleic acid content of the macronucleus. But it is significant that a situation analogous to pro-metaphase occurs at no time in the history of the ciliate macronucleus, for never does it lose its nuclear membrane, nor does its material ever come in direct and open communication with the cytoplasm. Hence, if cytoplasmic nucleotides pass into the nucleus, they must do so through the nuclear membrane. Painter[2] has recently reported the presence of large quantities of ribose nucleotides in the cytoplasm of ciliates, and the formation of macronuclear buds and their disorganization in the cytoplasm[2,6] must release large quantities of nucleic acid there. These would find their way back, ultimately, into the nucleus at the time of its growth.

There is still a final point to which we would refer, *i.e.*, the origin of amitosis of the