MITOCHONDRIAL AND NUCLEAR INTERACTION

By LEONARD ORNSTEIN

(From the Cell Research Laboratory, Mount Sinai Hospital, and the Department of Zoology, Columbia University, New York)

PLATES 116 AND 117

One of the things that differentiates cells from "bags of enzymes" is their ability to have the right thing at the right place at the right time. How they do it is one of the central problems of cellular physiology. That their *activities* are ordered is easily demonstrated, but changes in *spatial distribution* of cellular components with change in function has not often been easily observable.

Pollister, Gettner, and Ward (1) have described the structure of the nuclear membrane of the *early* oocyte of the tadpole of the green frog, *Rana clamitans*. The membrane consists of an elaborate net of pore-like rings with processes extending from the nucleus through the rings and a few tenths of a micron into the cytoplasm.

This note involves a demonstration of a remarkable relationship which occurs during a limited phase of this early period of development, between these nuclear processes and the mitochondria of the oocyte. These observations represent part of the results of the continuing studies on oocyte maturation that have been going on at Columbia University. This particular relationship became apparent only recently when we began to use rather thick sections for survey and orientation.

Fig. 1 shows a phase contrast micrograph of a 1 micron section of an oocyte in this special phase of its development. Numerous mitochondria and cytoplasmic granules can be discerned. Right along two regions of the nuclear membrane, clear cut aggregations of granular material are evident. Most of the remainder of the membrane appears rather thick, but no detail can be made out.

Fig. 2 is an electron micrograph of a 0.2 micron section of the same phase of oocyte development. A thick section is shown to include a sufficient number of nuclear membrane processes to make their relationship to the aggregations along the membrane more apparent. The membrane passes somewhat obliquely through the section, and details of a number of the rings may be made out. As can be seen, the processes converge on and seem to "fuse" with the aggregations. These consist in part of groups of mitochondria and denser material with ill defined internal structure, not unlike that of the substance of the processes themselves. Figs. 3 and 4 show portions of the previous field at higher magnification. Here we can see that the mitochondria are closely applied to the denser material which seems to be continuous with the nuclear membrane processes—

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as if we have caught the nucleus and mitochondria in the process of cooperatively producing the denser masses. Some rings with their central dots can be more clearly seen.

Preliminary ultraviolet photographs at 2537 A show that the dense material has an extremely high absorption. We have not as yet been able to determine whether this represents ribonucleic acid and/or protein. The Feulgen reaction is negative. It is colorless in 1 micron sections and therefore probably does not represent osmic oxide deposits. Since the egg is "preparing" for later development and differentiation, there are a large number of attractive hypotheses as to what might be going on.

The cytologist and cell physiologist have long speculated about the part played by cytoplasmic streaming in relation to the transport of mitochondria to regions where their special enzyme systems are in demand. The "cooperation" of the nucleus and mitochondria has played a central role in such speculations. Close apposition of the nucleus and mitochondria during certain limited functional periods has occasionally been observed in living cells—demonstrated especially strikingly in some of the "movies" of Frederic and Chèvremont (2) —as well as in sectioned material. This has been extremely suggestive—but prosecution of the culprits has been hampered by lack of any visual evidence of the merchandise of their transactions. Perhaps we now have one foot in the door.

REFERENCES

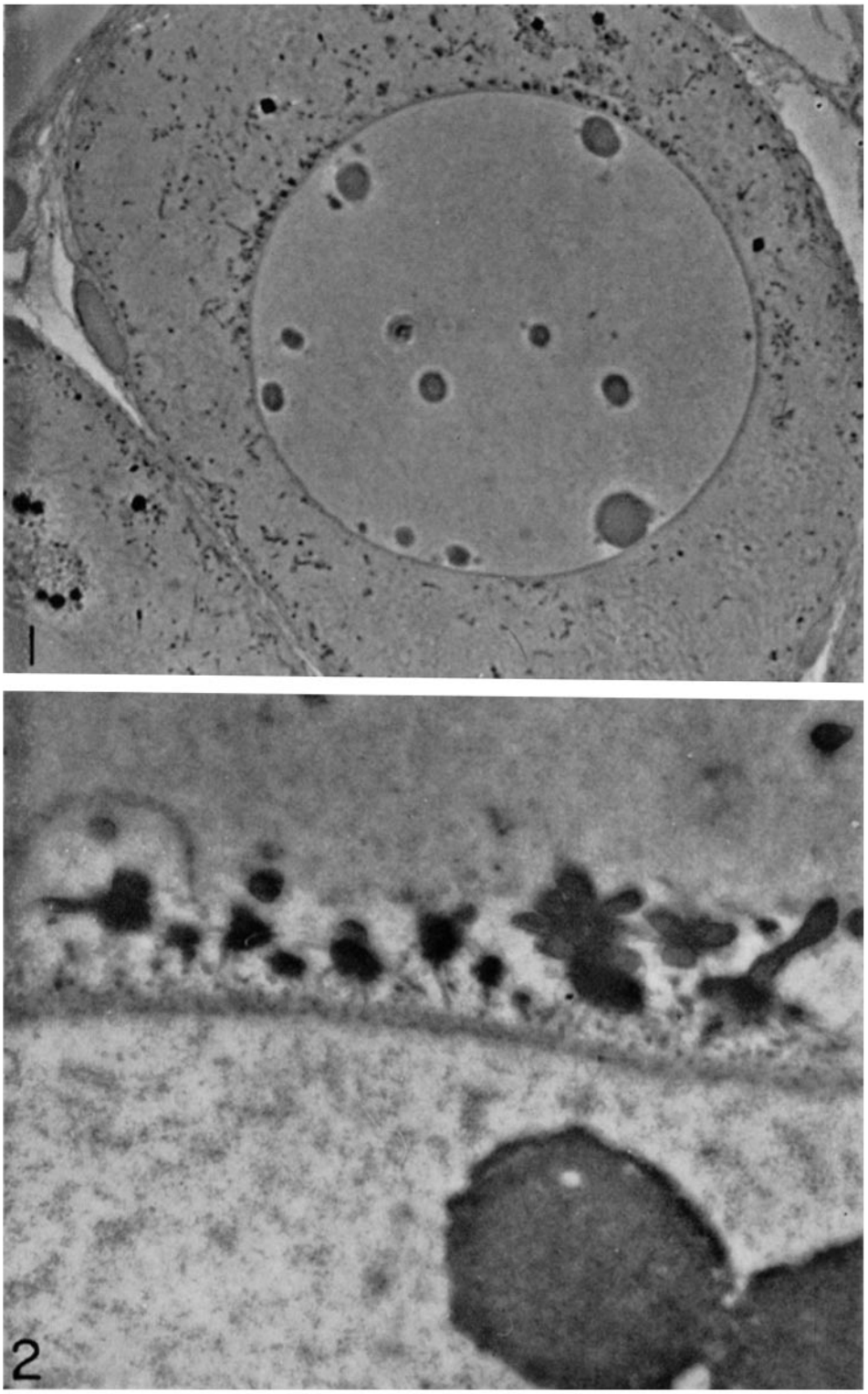
1. Pollister, A. W., Gettner, M. E., and Ward, R., *Science*, 1954, **120**, 789.
2. Frederic, J., *Ann. New York Acad. Sc.*, 1954, **58**, 1246.

EXPLANATION OF PLATES

PLATE 116

FIG. 1. Photomicrograph of an *early* oocyte from the ovary of a tadpole of the frog, *Rana clamitans*. Fixed in 2 per cent OsO_4 (adjusted to pH 7.4) for 15 minutes, then washed and postfixed in 2 per cent formaldehyde at pH 7.4 for 24 hours. Embedded in *n*-butyl methacrylate. Sectioned at 1 micron. Embedding removed with CCl_4 and mounted in oil of refractive index, $n = 1.46$. Medium dark phase contrast objective, × 1,600.

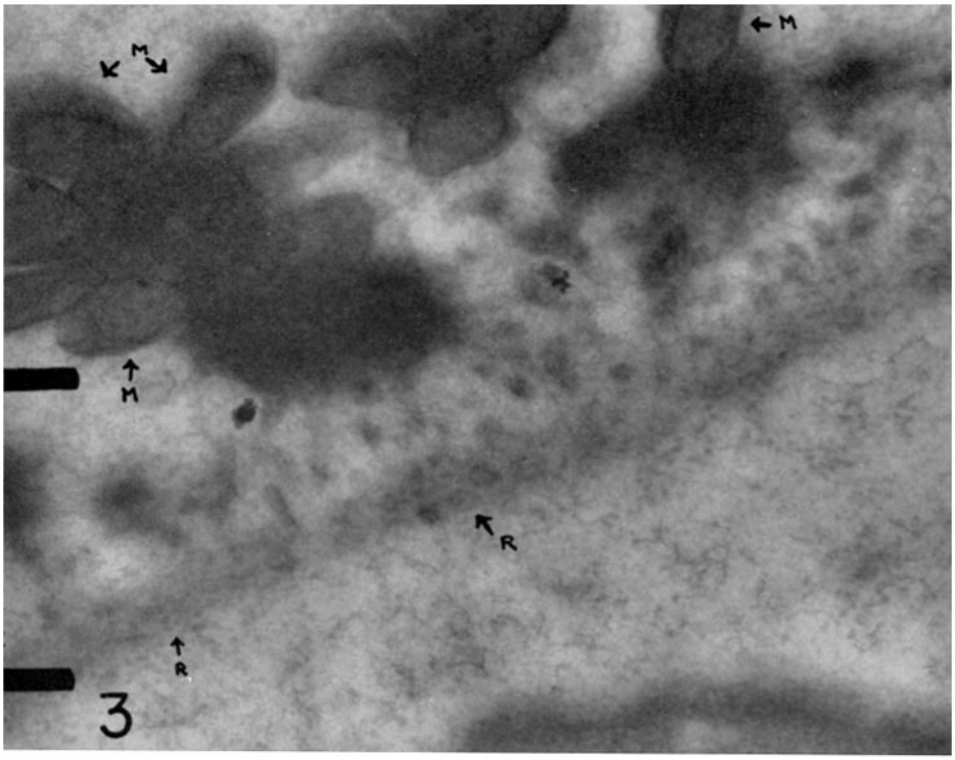
FIG. 2. Same material; electron micrograph of 0.2 micron section. Philips EM 100A at 100 kv. × 16,000.

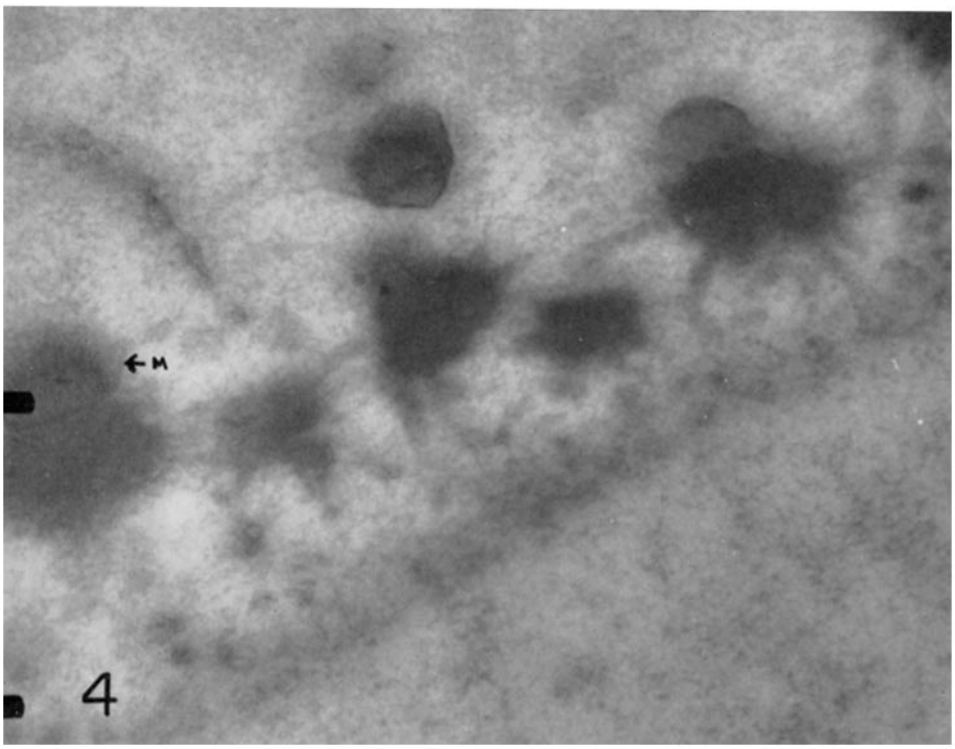


(Ornstein: Mitochondrial and nuclear interaction)

PLATE 117

FIGS. 3 and 4. Same section at higher magnification. *M*, mitochondrion, *R*, ring. × 40,000.





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