Modes of Restoring Diploidy

Biology of Fertilization. CHARLES B. METZ and ALBERTO MONROY, Eds. Academic Press, Orlando, FL, 1985. In three volumes. Vol. 1, Model Systems and Oogenesis. xviii, 391 pp., illus. $75. Vol. 2, Biology of the Sperm. xx, 475 pp., illus. $75. Vol. 3, The Fertilization Response of the Egg. xviii, 469 pp., illus. $75.

Fertilization occurs but once in the life history of the organism, but the changes associated with fertilization are not once-in-a-lifetime events. Rather, the few seconds around sperm-egg contact represent a microcosm of cell biological phenomena, including cell-cell recognition, cell attachment, cell fusion, signal transduction involving polyphosphoinositides, calcium, and *p*H increases, exocytosis, endocytosis, changes in actin and tubulin, a large augmentation of protein synthesis, and, finally, initiation of DNA synthesis, which ultimately culminates in a series of rapid mitotic divisions.

Overlying the vast number of cellular and chemical changes, the morphological aspects of fertilization seem boringly similar among different species—a small motile sperm fuses with a large nonmotile egg, and this interaction somehow triggers development. Yet one comes away from reading this three-volume collection awed by the different mechanisms used to achieve the same end.

A good example of the similarities and differences is seen in the mechanisms by which oocytes of different organisms complete the meiotic divisions. The oocyte remains in meiosis until just prior to ovulation; the completion of meiosis and the formation of the haploid cell is then typically triggered by a hormonal system. In the best-studied cases—oocytes of starfish and frogs—a neuropeptide acts on the ovarian cells to produce a substance that has a low molecular weight, and this then acts at the cell surface to induce completion of meiosis and associated changes that allow the egg to be fertilized. As reviewed in excellent papers by Kanatani and Masui, the principles used are similar but the actors are radically different. The dissimilar actors are the hormones—the starfish uses a nucleoside derivative and the frog a steroid. The similarity is that in all cases the cascade of events ensuing from the interaction of hormone and plasma membrane results in the formation of similar cytoplasmic proteins that then induce meiosis. The same principle is apparently used in all cells for meiosis or mitosis—one can extract protein factors from dividing somatic cells that may be identical to the factors produced in oocytes and that act by causing a breakdown of nuclear membranes and the condensation of chromosomes.

An even more striking example of how the same ends are achieved by different means is seen in an elegant review by Tilney on the acrosome reaction and the formation of the acrosomal process. The acrosomal process is an extension of the cell, forming at the apical end of the sperm upon contact with the egg jelly. In echinoderm sperm, the formation of the acrosomal process involves an explosive polymerization of actin. In horseshoe crab sperm, actin filaments are already preformed and the extension of the acrosomal process occurs via changes in the twist or pitch of the coiled actin filaments. Here then different mechanisms achieve the identical morphological outcome.

A final example is an apparent molecular coevolution in the mechanisms by which the sperm approximates contact with the egg surface preparatory to fusion. Eggs are typically surrounded by an envelope (the chorion), and sperm possess mechanisms to pass through this envelope to get to the egg surface. Hoshi reviews these rites of passage and notes that in most cases the entry is via activity of hydrolytic enzymes associated with the sperm. In some cases, however, a nonenzymatic mechanism is used in which sperm-associated proteins somehow destabilize the egg envelope so that a hole is made through which the sperm can pass. No hydrolases are involved. Clearly, reciprocal evolutionary changes in both sperm and egg components must have occurred in order for this novel mechanism to be used.

To be sure, there are similarities in how embryonic development is initiated. It appears that in all cases activation ensues from receptor-mediated increases in cytosolic calcium in the egg. But even here there may be phyletic variations. Jaffe notes that calcium is released from cytoplasmic stores in some types of eggs, whereas in others the Ca^{2+} increase comes from influx into the egg.

The evolutionary caprices surrounding fertilization, which I have chosen to emphasize in this review, are really not surprising. The developmental stages centering on formation of the gametes and their fertilization are really the arena where evolutionary variation occurs. The ability to move to different environments, for example from aquatic to terrestrial, depended on evolving new types of egg coats. Meiosis is synonymous with crossing-over, gene recombination, and the opportunity for gene duplications in the germline. Fertilization involves species-specific reciprocal receptors for gamete binding, and changes in these receptors would favor reproductive isolation and subsequent speciation.

Many of the phenomena associated with early development are covered in these three volumes. There are chapters on egg and sperm formation, egg and sperm maturation, adhesion, recognition, and chemotaxis in prokaryotes and eukaryotes as well as important papers on the aforementioned cell biological phenomena. There are also chapters on embryological concomitants of fertilization, such as a paper by Malacinski on fertilization and axis formation in amphibian embryos and important reviews from the labs of Davidson and Raff on the macromolecular correlates of early embryogenesis.

This series provides a good review of fertilization, circa 1986, and is published almost 20 years after the first similar treatise. I suspect that the next update will be needed much sooner and that at that time an even better understanding and appreciation of the similar, yet so varied, modes of restoring diploidy will be available.

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Apis mellifera

Honeybee Ecology. A Study of Adaptation in Social Life. THOMAS D. SEELEY. Princeton University Press, Princeton, NJ, 1985. x, 202 pp., illus. $39.50; paper, $14.50. Monographs in Behavior and Ecology.

In science as in history the honeybee *Apis mellifera* has reigned as our premier social insect. William Morton Wheeler observed that in antiquity its great industry and many useful products, of mysterious origin, made the honeybee "a divine being, a prime favorite of the gods, that had somehow survived the golden age or had voluntarily escaped from the garden of Eden with poor fallen man for the purpose of sweetening his bitter lot." In more recent times it has become one of the most intensively studied of all animal species, especially with reference to behavior and social organization.

Research on the honeybee in this century can be divided into two principal periods. The first, led by Karl von Frisch from 1914 into the 1950's, stressed physiology and ethology. A great deal was learned about what honeybees do: the basic properties of their sensory perception, division of labor, colony life cycle, aging, communication by pheromones, the now-famous waggle dance, and other aspects, enough to fill tens of thousands of articles in over 20 journals devoted entirely to the species. During the