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Review
Ion Currents in Embryo Development

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Ion channels are proteins expressed in the plasma membrane of electrogenic cells. In the zygote and blastomeres of the developing embryo, electrical modifications result from ion currents that flow through these channels. This phenomenon implies that ion current activity exerts a specific developmental function, and plays a crucial role in signal transduction and the control of embryogenesis, from the early cleavage stages and during growth and development of the embryo. This review describes the involvement of ion currents in early embryo development, from marine invertebrates to human, focusing on the occurrence, modulation, and dynamic role of ion fluxes taking place on the zygote and blastomere plasma membrane, and at the intercellular communication between embryo cell stages.

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Key words: embryo; early development; ion channels; ion currents; gap junctions

Embryogenesis

Embryonic development is a complex multistep process that starts when the oocyte is fertilized by a sperm. Subsequent cell divisions, migration, differentiation, and growth transform the oocyte in the zygote, that is, the first cell of the new organism that marks the beginning of embryo development. Shortly after its formation, the zygote starts to cleave, undergoing repeated mitotic divisions, which give rise to an increase in the number of cells, that is, the blastomeres. Depending on the species, there is a different timing of embryo development; however, as a general rule the blastomeres become smaller and start to align in a layer to form a compact structure that allows communication between each other. During cleavage, each blastomere undergoes a commitment to form different tissues. High contribution to the knowledge of cell fate specification comes from the cell-lineage studies performed in ascidians at the beginning of the last century (Conklin, 1905). In this species, the 8-cell stage is critical because all the tissue of the future embryo is segregated in some specific blastomere and recognizable by specific pigmentation. The segregation of cell lines in different blastomeres of the early embryo is known as cell lineage, and provides basic information on the kind and position that different tissues will occupy inside the embryo (Satoh, 1994).

A similar situation occurs in sea urchin embryos at the fourth cleavage division (Cameron and Davidson, 1991). Once the stage of ~32 blastomeres is reached, the embryo is a morula, a uniform aggregate of undifferentiated cells that is ready to undergo into cavitation, the polarizing event that accompanies the transformation from morula to blastocyst.

Generation of polarity is a basic event for establishing the embryonic architecture. The acquisition of cell polarity and primary differentiation of early cell lineages are spatially and temporally interdependent processes (Fleming and Johnson, 1988).

The blastocyst is the early embryonic stage in which a fluid-filled cavity first appears, and differentiated cells are arranged into: (i) the trophectoderm, a thin flat outer layer of epithelial cells, which gives rise to embryonic support structures, and (ii) the inner cell mass, a group of centrally located cells, which constitute the embryo itself. Early embryogenesis includes blastulation, and in some species gastrulation and neurulation, whereas later events account for organ formation and the establishment of three-dimensional multicellular structures. Depending on the species with external or internal fertilization, the steps that conclude embryogenesis are the formation of swimming larvae and subsequent metamorphosis in marine invertebrates versus embryo implantation in the female genital tract in mammals (Alberts et al., 1983; Menezo and Renard, 1993).

In all these contexts, although the details are species-specific, cell surface, and intercellular devices, such as ion channels, play a fundamental role at different developmental stages of all the animal species studied (see Tosti, 2010 for comprehensive review, Fig. 1, Table 1).

Electrical Properties of Plasma Membrane

The cell plasma membrane has peculiar electrical properties due to a different distribution of electrical charges through the lipid bilayer known as voltage, that in turn generates a transmembrane potential, that is, the resting potential (RP), which is negative in almost all cells studied.

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