Section A1: The Stages of Early Embryonic Development

1. From egg to organism, an animal’s form develops gradually: the concept of epigenesis
2. Fertilization activates the egg and bring together the nuclei of sperm and egg
3. Cleavage partitions the zygote into many smaller cells
1. From egg to organism, an animal’s form develops gradually: the concept of epigenesis

- **Preformation**: the egg or sperm contains an embryo that is a preformed miniature adult.

- **Epigenesis**: the form of an animal emerges from a relatively formless egg.

- An organism’s development is primarily determined by the genome of the zygote and the organization of the egg cytoplasm.
2. Fertilization activates the egg and bring together the nuclei of sperm and egg

- Sea urchins are models for the study of the early development of deuterostomes.
  - Sea urchin eggs are fertilized externally.
  - Sea urchin eggs are surrounded by a jelly coat.
Fig. 47.2

1. Contact
2. Acrosomal reaction
3. Growth of acrosomal process
4. Fusion of the plasma membranes of the sperm and egg.
5. Cortical reaction
6. Entry of sperm nucleus
• The Acrosomal Reaction.

  • **Acrosomal reaction**: when exposed to the jelly coat the sperm’s acrosome discharges its contents by exocytosis.

  • Hydrolytic enzymes enable the **acrosomal process** to penetrate the egg’s jelly coat.

  • The tip of the acrosomal process adheres to the vitelline layer just external to the egg’s plasma membrane.
• The sperm and egg plasma membranes fuse and a single sperm nucleus enter the egg’s cytoplasm.
  
  • Na\(^+\) channels in the egg’s plasma membrane opens.
  
  • Na\(^+\) flows into the egg and the membrane depolarizes: **fast block to polyspermy.**
• The Cortical Reaction.
  • Fusion of egg and sperm plasma membranes triggers a signal-transduction pathway.
    • Ca$^{2+}$ from the eggs ER is released into the cytosol and propagates as a wave across the fertilized egg $\rightarrow$ IP$_3$ and DAG are produced.
    • IP$_3$ opens ligand-gated channels in the ER and the Ca$^{2+}$ released stimulates the opening of other channels.
• High concentrations of Ca$^{2+}$ cause **cortical granules** to fuse with the plasma membrane and release their contents into the perivitelline space.

• The vitelline layer separates from the plasma membrane.

• An osmotic gradient draws water into the perivitelline space, swelling it and pushing it away from the plasma membrane.

• The vitelline layer hardens into the **fertilization envelope**: a component of the **slow block to polyspermy**.

• The plasma membrane returns to normal and the fast block to polyspermy no longer functions.
• Activation of the Egg,
  
  • High concentrations of Ca\textsuperscript{2+} in the egg stimulates an increase in the rates of cellular respiration and proteins synthesis.

  • In sea urchins, DAG activates a protein that transports H\textsuperscript{+} out of the egg.
    
    • The reduced pH may be indirectly responsible for the egg’s metabolic responses to fertilization.

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• In the meantime, back at the sperm nucleus...
  • The sperm nucleus swells and merges with the egg nucleus → diploid nucleus of the zygote.
  • DNA synthesis begins and the first cell division occurs.
• **Fertilization in Mammals.**

• **Capacitation**, a function of the female reproductive system, enhances sperm function.

  • A capacitated sperm migrates through a layer of follicle cells before it reaches the **zona pellucida**.

  • Binding of the sperm cell induces an acrosomal reaction similar to that seen in the sea urchin.
• Enzymes from the acrosome enable the sperm cell to penetrate the zona pellucida and fuse with the egg’s plasma membrane.
  
  • The entire sperm enters the egg.
  
  • The egg membrane depolarizes: functions as a fast block to polyspermy.
  
  • A cortical reaction occurs.
  
  • Enzymes from cortical granules catalyze alterations to the zona pellucida: functions as a slow block to polyspermy.
• The envelopes of both the egg and sperm nuclei disperse.

• The chromosomes from the two gametes share a common spindle apparatus during the first mitotic division of the zygote.
3. Cleavage partitions the zygote into many smaller cells

- **Cleavage** follows fertilization.
  - The zygote is partitioned into **blastomeres**.
    - Each blastomere contains different regions of the undivided cytoplasm and thus different cytoplasmic determinants.
• Except for mammals, most animals have both eggs and zygotes with a definite polarity.

• Thus, the planes of division follow a specific pattern relative to the poles of the zygote.

• Polarity is defined by the heterogeneous distribution of substances such as mRNA, proteins, and yolk.

• Yolk is most concentrated at the vegetal pole and least concentrated at the animal pole.

• In some animals, the animal pole defines the anterior end of the animal.
• In amphibians a rearrangement of the egg cytoplasm occurs at the time of fertilization.

• The plasma membrane and cortex rotate toward the point of sperm entry.
  • The **gray crescent** is exposed and marks the dorsal surface of the embryo.

• Cleavage occurs more rapidly in the animal pole than in the vegetal pole.
• In both sea urchins and frogs first two cleavages are vertical.
• The third division is horizontal.
• The result is an eight-celled embryo with two tiers of four cells.

Fig. 47.8a
• Continued cleavage produces the **morula**.
• A **blastocoepl** forms within the morula → **blastula**
• In birds the yolk is so plentiful that it restricts cleavage to the animal pole: **meroblastic cleavage**.

• In animals with less yolk there is complete division of the egg: **holoblastic cleavage**.