Sea urchins (what phylum?) are models for the study of the early development of deuterostomes (like us, right?).

• Sea urchin eggs are fertilized externally.
• Sea urchin eggs are surrounded by a jelly coat, and a vitelline layer just underneath the plasma membrane. Watch 6:05
It’s what’s for breakfast....

spoons
• **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 due to molecules in each membrane connecting like enzyme and substrate. This specificity prevents cross-species fertilization.

• Communication by DIRECT CONTACT
Activation of the Egg,

- Calcium gates open, and high concentrations of Ca$^{2+}$ in the egg causes an increase in cellular respiration and protein synthesis.
- mRNA present before fertilization is translated to make the proteins necessary.
- Cytoplasmic determinant.
• **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** is pulled in by extensions of the egg cell membrane called microvilli.

• There is, however, no fast block to polyspermy in mammals. The book says there is, but further digging led to this description: there is a block caused by depolarization of the membrane, but it is much slower than in sea urchins. So maybe call it a membrane block, but not a *fast* block.

• According to the Jewish tradition in the Talmud, Goliath was born by polyspermy, and had about one hundred fathers.
A block by the outer layers does occur:

• A **slow block** called a **cortical reaction** occurs.
  
  • Enzymes from cortical granules catalyze hardening of the **zona pellucida**: 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. And now, it is time to develop!!
6. Amniote embryos develop in a fluid-filled sac within a shell or uterus

- The amniote embryo is the solution to reproduction in a dry environment.
  - Shelled eggs of reptiles and birds.
  - Uterus of placental mammals.
  - The name comes from the amnion, a membrane surrounding the embryo.

Remember amniocentesis? Remember some evolution links? Decent 4 min.
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 former zygote’s cytoplasm and thus different cytoplasmic determinants (what would they be?).
• Continued cleavage produces the **morula**, a *solid* ball of cells.

Fig. 47.8b
• A **blastocoel** forms within the morula, now called a blastula.
• Check this on stem cells. 10 min. or so.

• This is the general idea, but cloning shows that even a differentiated cell nucleus retains the ability to act like a stem cell if its surrounding cytoplasm is changed, as when put in an egg.

• This is called genomic equivalence.
• Biotechnologists have adopted *in vitro* ways to create and clone novel plants varieties.

• Whole plants are cultured from small tissue pieces or even single parenchyma cells, on an artificial medium containing nutrients and hormones.

• Through manipulations of the hormonal balance, the callus that forms can be induced to develop shoots and roots with fully differentiated cells.
4. Gastrulation rearranges the blastula to form a three-layered embryo with a primitive gut

- **Gastrulation** rearranges the embryo into a triploblastic **gastrula**.
  - The embryonic germ layers are the **ectoderm, mesoderm**, and **endoderm**.
  - This is a critical event in development.
  - If this process doesn’t proceed correctly, body parts may develop in the wrong place…
Now it is time for a baby to start forming all its parts in the right places.

- Organogenesis begins with the formation of the **neural tube**, **notochord**, and **somites**.
- Let’s watch some good video, How Babies Get Made (watch first 18 minutes).
5. In organogenesis, the organs of the animal body form from the three embryonic germ layers

• The **ectoderm** gives rise to the:
  • Epidermis of skin, and its derivatives
  • Epithelial lining of the mouth and rectum.
  • Cornea and lens of the eyes.
  • The nervous system; adrenal medulla; tooth enamel; epithelium of the pineal and pituitary glands.
• The endoderm germ layer forms:
  • The epithelial lining of the digestive tract (except the mouth and rectum).
  • The epithelial lining of the respiratory system.
  • The liver, pancreas, thyroid, parathyroids, thymus, and the lining of the urethra, urinary bladder, and reproductive systems.
• The **mesoderm** gives rise to:
  • The notochord.
  • The skeletal and muscular systems.
  • The circulatory and lymphatic systems.
  • The excretory system.
  • The reproductive system (except germ cells).
  • And the dermis of skin; lining of the body cavity; and adrenal cortex.
How do germ cells, the ones that end up making gametes, get where they end up?

Here’s a neat story in claymation about germ cells, multicellularity, and natural selection. Very cool! Show for sure😊

Check it out 4:35
Section B: The Cellular and Molecular Basis of Morphogenesis and Differentiation in Animals

1. Morphogenesis in animals involves specific changes in cell shape, position, and adhesion

2. The developmental fate of cells depends on cytoplasmic determinants and cell-cell induction: a review

3. Fate mapping can reveal cell genealogies in chordate embryos

4. The eggs of most vertebrates have cytoplasmic determinants that help establish the body axes and differences among cells of the early embryo

5. Inductive signals drive differentiation and pattern formation in invertebrates
2. The developmental fate of cells depends on cytoplasmic determinants and cell-cell induction: a review

• Cytoplasmic determinants can be mRNA’s, proteins like transcription factors, and miRNA’s. An unequal distribution of these in the egg, zygote and early embryonic cells starts the process of differentiation.

• Then, induction kicks in. Some cells secrete inducers, signal molecules which reach other cells and start signal transduction pathways that make them differentiate.
a. Observable cell differentiation results from the expression of genes for tissue-specific proteins.

b. Induction of transcription factors during development results in sequential gene expression.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Homeotic genes are involved in developmental patterns and sequences.

2. Embryonic induction in development results in the correct timing of events.
4. Genetic mutations can result in abnormal development.

5. Genetic transplantation experiments support the link between gene expression and normal development.

6. Genetic regulation by microRNAs plays an important role in the development of organisms and the control of cellular functions.
Here’s the overall sequence of events:

• Determination: sets the developmental fate of cells.

• Differentiation: causes cells to use different genes and become different than other cells.

• Morphogenesis: shaping of differentiated cells into the multicellular body and its organs.

• Growth: by cell division and expansion.

• Let’s watch the rest of How Babies Get Made! 18:00 – end.
Here’s what plays a role in the timing and sequence of development:

- Morphogens: Cause change *directly*
- “inducer” had a different meaning talking about operons. Lactose was an inducer for the lac operon. THESE inducers trigger STP’s in cells.
- Homeotic (HOX) genes – remember PitX1 in sticklebacks?
- miRNA’s
- Let’s see an example of the morphogen bicoid.
Watch the discovery of how bicoid works as a morphogen.

- [http://www.youtube.com/watch?v=Ncxs21KEj0g](http://www.youtube.com/watch?v=Ncxs21KEj0g)
- First watch 8:40 – 11:00, then 14:00 – 19:30.
- During egg formation, bicoid RNA is anchored to the cytoplasm in one area – it will become the head. Then, as bicoid protein in the zygote begins to get made from the bicoid RNA, the protein diffuses and acts as a transcription factor to cause transcription of the hunchback gene in a gradient-based manner, which then turn on genes that establish segments, and then HOX genes cause each segment to form correctly. Cool, eh?
Nobel winner Eric Wieschaus (on the left)
Very similar events occur in mammal development

• But it is the unequal distribution of a family of Par (partitioning defective) proteins that determine polarity in ways that are still being figured out but that also involve asymmetrical distribution of spindle fibers during cytokinesis.
• Homeobox-containing (\textit{Hox}) genes play a role in specifying the identity of regions of the limb, as well as the body as a whole.

• Again, the PitX1 gene is an example.

• A homeobox is a DNA sequence that is the same in other homeotic genes.

• A homeodomain is the amino acid sequence coded for by the homeobox.

• Examples: The homeodomain of the lac repressor protein is the same as that of other DNA binding proteins in bacteria, yeast and ALL animals (even you).
HOX Genes can cause some strange things to happen if they mutate.
• In **induction**, interactions among the embryonic cells themselves induce changes in gene expression.

  • Inducers are chemicals that bind to receptors and cause a signal transduction pathway that leads to changes in a cell, usually by causing transcription of new genes.

  • Morphogens, on the other hand, don’t pass on a message, they **DIRECTLY** affect target cells.

  • Both work in a gradient-based manner; higher concentrations make a cell do this, lower concentrations make it do that. [Watch here](#) (2 min.)

• Here is a butterfly example.
Morphogens in the development of eye spots on a butterfly 1:05

- [http://www.youtube.com/watch?v=FCFWllMZ8uw](http://www.youtube.com/watch?v=FCFWllMZ8uw)
1. Morphogenesis in animals involves specific changes in cell shape, position, and adhesion.

- Changes in cell shape usually involves reorganization of the cytoskeleton.

- Here are examples of induction.

Fig. 47.16
• The “Organizer” of Spemann and Mangold.

• Grafting the dorsal lip of one embryo onto the ventral surface of another embryo results in the development of a second notochord and neural tube at the site of the graft.

• Spemann referred to the dorsal lip as a primary organizer.

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And in 2018, this organizer was found in human embryos

- Ethical restrictions on use of human embryos made it harder to find, but it was completely predictable. When grafted onto a chick embryo, these cells induced the formation of a chick nervous system. They are the red cells here:
• Pattern Formation in the Vertebrate Limb.

• Induction plays a major role in pattern formation.

  • Positional information, supplied by molecular cues, tells a cell where it is relative to the animal's body axes.

• The following is another good one to know as an example of induction.
• Limb development in chicks as a model of pattern formation.

• Wings and legs begin as limb buds.
  • Each component of the limb is oriented with regard to three axes:
    • Proximal-distal
    • Anterior-posterior
    • Dorsal-ventra.
• Organizer regions.
• Apical ectodermal ridge (AER).
  • Secretes fibroblast growth factor (FGF) proteins. These are inducers.
  • Required for limb growth and patterning along the proximal-distal axis.
  • Required for pattern formation along the dorsal-ventral axis.
• **Zone of polarizing activity (ZPA).**
  
  • Secretes *the morphogen Sonic Hedgehog*, a protein growth factor.
  
  • Required for pattern formation of the limb along the anterior-posterior axis.
  
  • Sonic Hedgehog diffuses from the ZPA cells to surrounding cells. Those nearest get the highest dose and become little finger, those furthest away become thumb.
  
  • Watch Your Inner Fish, Episode 1 Sonic Hedgehog
• Organizer regions.
2.E.1.b.6. What is the role of microRNAs in the development of organisms?

2.E.1.c. Explain how programmed cell death (apoptosis) effect normal development and differentiation by using one of the below examples.

- Morphogenesis of fingers and toes
- Immune function
- C. elegans development
- Flower development
Now, the role of apoptosis in the classic example of finger and toe development

- Under the direction of RNAi by miRNA’s, cells that form webbing between fingers and toes begin to die between days 41 to 56 of human development.
If, by mutation, they don’t…
And here is a plant example: flower development.

- There are 3 classes of Organ Identity Genes, analogous to HOX genes in animals.
Soooo…to rap it up…

- Let’s *reeeggggulate it!* 2:30
- Now you can understand this better too.
- [http://www.youtube.com/watch?v=osWuWjbeO-Y](http://www.youtube.com/watch?v=osWuWjbeO-Y)