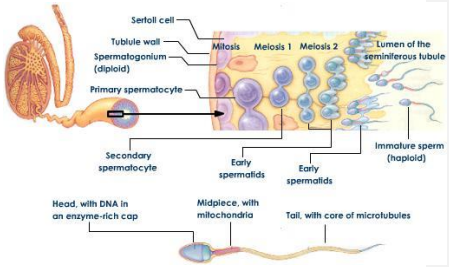
Reproduction and Developmental Biology
Biology Olympiad
November 8, 2019

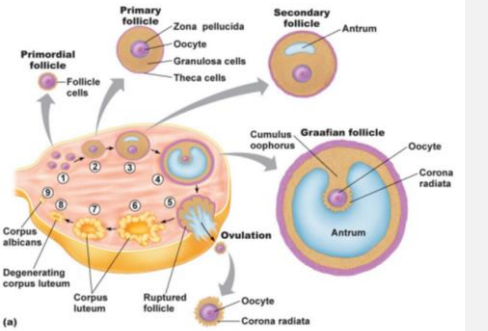
Sperm development

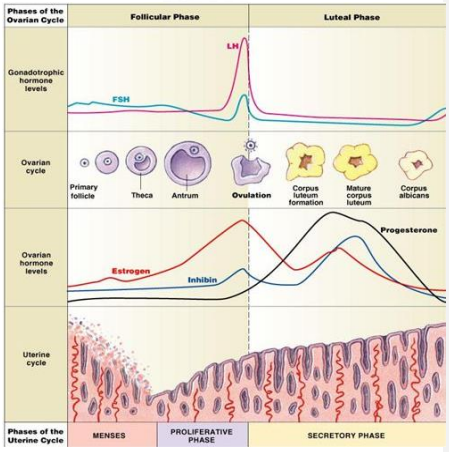
- **Maturation from out to in**, eventually reaching the lumen of seminiferous tubule
- Primary germ cell - (mitosis) -> spermatogonia - (mitosis) -> primary spermatocytes - (meiosis I) -> 2 secondary spermatocy
- tes - (meiosis II) -> 4 spermatids -> spermatozoa/sperm cells
- **Sertoli cells** found within the tubule, **Leydig cells** found in surrounding interstitium
- Path: seminiferous tubules for maturation, also peristalsis -> become motile in epididymis -> vas deferens, a muscular duct -> urethra
- Before it leaves the urethra, the seminal vesicles, prostate gland, and bulbourethral glands (all **accessory glands**) add fructose and citrate, coagulating/anticoagulating enzymes, mucus, and prostaglandins.

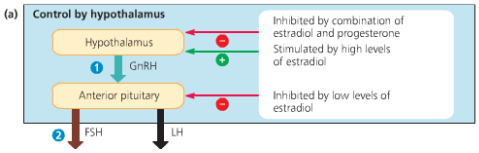


Egg development (a bit complicated, but worthwhile)
(see folliculogenesis on wiki for more)

- Key ideas to supplement Campbell:
- The lack of a FSH surge is due to the gradual secretion of inhibin by granulosa cells in the follicle (logically, if you have lots of follicles then there should be a signal to slow it down)
- Thecal cells on the outside of the follicle are highly sensitive to LH, and enhance estrogen production, so the LH and estrogen surge are intertwined
- Progesterone (pro + gestation) is the **primary** product of the corpus luteum, and LH stimulates its growth
    - Thus, another negative feedback system, as progesterone+estrogen will lower LH and cause atresia (degeneration) - note the uptick when progesterone+estrogen fall
    - The corpus luteum is "rescued" by fertilization, since implanted embryo sends human chorionic gonadotropin







(hCG) which **mimics** LH

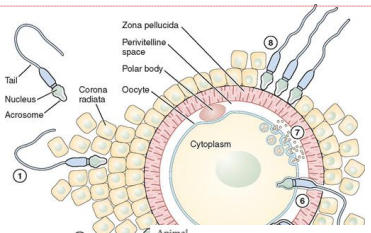
General idea: **Fertilization -> Cleavage -> Gastrulation -> Organogenesis** (Last two cause **morphogenesis**)

Fertilization: (Campbell diagrams are very useful)

- **Polyspermy is fatal**, so mechanisms to prevent are evolutionarily important

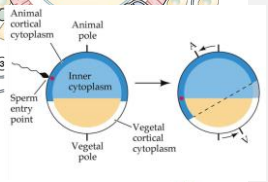
Sea Urchins (Model organism, because external fertilization, large eggs, and the phylum Echinodermata is more related to Chordata)

- **Fast block to polyspermy** = inflow of Na^+ depolarizes egg
- **Slow block to polyspermy** = Ca^{2+} wave triggered by signal transduction (IP_3), release from smooth ER, causes cortical granule (vesicle) exocytosis, which hardens vitelline layer into **fertilization envelope** and creates a **perivitelline space** - also **causes egg activation**



Mammals (on right)

- **No fast block**, but slow block similar to sea urchins. Has corona radiata (follicle cells) and zona pellucida (similar to vitelline layer), whereas sea urchin had egg jelly and vitelline layer

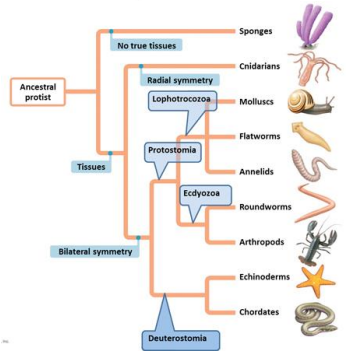


Cortical rotation toward the sperm entry exposes a **gray crescent** (future dorsal side)

- Animal pole = gray pigment, vegetal pole = yolky

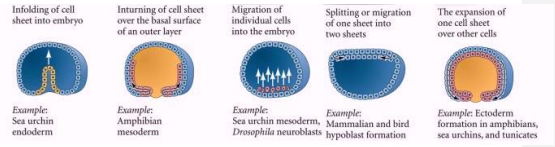
Cleavage (rapid cell division of zygote, with little volume growth)

- 16-cell stage = **morula**, 128 cells = **blastula** (or **blastocyst** if mammal), basically a ball with a fluid-filled cavity called the **blastocoel** (-coel = cavity)
- Mammals are totipotent up until 8-cell stage
- **Holoblastic**, complete cleavage (annelids, echinoderms, mammals) and **meroblastic**, incomplete cleavage due to lots of yolk (reptiles/birds, insects, fish)



Gastrulation (establishment of cell layers and digestive tube)

- **Protostomes** (proto = first, stoma = mouth) first opening (**blastopore**) becomes the mouth, second is anus
- **Deuterostomes** (deutero = second) the second opening is the mouth, **blastopore is anus**
- Visualizing can be tough, so focus on the key types of movements
- **Convergent extension** is what enables much of these cell movements
- Some key points:
    - The **archenteron** is the initial depression that gives rise to the gut
    - Chick embryo is very yolky, so only the tip of the embryo can fold. *Delamination* forms the **epiblast** = embryo proper, basically the entire embryo, and the **hypoblast**, which becomes the stalk that connects yolk to embryo later. **Primitive streak** is where cells *ingress* and form endoderm and mesoderm
    - In mammals, the blastocyst, consisting of an **inner cell mass** and trophoblast, implants - ICM forms epiblast and hypoblast which is the **embryo proper**. Has primitive streak like chicks
    - **Trophoblast** is a bunch of finger-like projections, they invade the endometrium and produce **extraembryonic membranes**
    - **Amnion** (cushioning), **chorion** (gas exchange), **allantois** (waste, umbilical cord for mammals), and **yolk sac** (food source and forms blood cells later in mammals)



Organogenesis (formation of specific organs)

- The main example is **neurulation** - see Campbell
- Signals from other embryonic tissue cause the ectoderm to thicken (microtubule action) and form the **neural plate** - cells pinch off from actin filament contraction to form **neural tube** which becomes spine (B9/folic acid deficiency causes spina bifida where it can't form a tube properly; the **neural fold** on the lateral edges of the neural plate becomes **neural crest cells**
- **Cytoskeleton** and glycoproteins called **cell adhesion molecules (CAMs)**

Cell Fate Determination

Commented [1]: Amniotes (terrestrial animals with amniotic sac, including reptiles and mammals) have adaptations to prevent water loss or damage
Egg - found in birds and other reptiles, and monotremes (egg-laying mammals)
Internal fertilization - order Marsupialia, has a partial period in the uterus, rest in pouch; Eutherians have complete fetal development in uterus, and has placenta

- **Positional information** (molecular cues) from surrounding tissues signals tissues to be **determined** to a certain fate (committed), then **differentiate** into it. Induction is used in process of **pattern formation**
- Three axes: proximal-distal, anterior-posterior, ventral-dorsal
    - **Apical ectodermal ridge (AER)** - releases **fibroblast growth factor**, or FGF, which causes *proximal* end to have limb bud growth
    - **Zone of polarizing activity (ZPA)** - releases **sonic hedgehog**, which signals the *posterior* side to develop (little fingers)
    - **Bone morphogenetic protein-4 (BMP-4)** is inactivated on the dorsal side to cause *dorsal* structures