BIOL 1030
Introduction to Biology: Organismal Biology, Spring 2011
Section A

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Right up front — a warning about today's lecture:

If explicit sexuality bothers you, leave class right after I discuss the points on this and the next slide. I will be discussing sexual anatomy and sexual processes throughout today's lecture. But I don't want to offend anyone, so I'm giving you the chance to bail!

Even if you do so, you are responsible for the material, and there is an in-class assignment today.
If you decide to leave now, complete the assignment during this class period, regardless, and turn it in to me, in my office after class ends. I will not accept them after that!

Here’s the assignment: Most mammals, including all other primates, have a bone in their penis called the baculum, but Homo sapiens lost it in their evolution. In street talk, “There is no bone in our boner.” A few other mammals also secondarily lost the baculum — including horses, rabbits, hyenas, and whales — and it is quite reduced, yet present, in the other Great Apes. Why do you think that humans lost the baculum in their evolution? Try to use sound evolutionary thought in your answer. What possible adaptive advantage could be attributed to this loss?
Animal reproduction, embryology, and development

You gotta start somewhere — how we change from separate sperm and egg cells, to a fertilized egg (the zygote), and eventually into a fully formed human being.
All multicellular organisms reproduce, develop, and grow.

- **Asexual reproduction** – produces identical clones, advantageous in unchanging environment.
- **Sexual reproduction** – genetic diversity increases reproductive success in a changing environment.
- **Germ cells create gametes** – these are the haploid sex cells produced by meiosis (except in plants).
- **Fertilization unites gametes** to produce a diploid zygote in all forms of sexual reproduction.

It can work two ways. Either . . .

- **External fertilization**, or . . .
- **Internal fertilization**.
Most critters that we think of use internal fertilization, like what produced this baby tortoise — the male copulates with the female to fertilize the egg in her body.

With another youngster looking on!
No shame.
But not all critters do it that way. Many invertebrates, fish, and amphibians use external fertilization. Not nearly as much fun, but it gets the job done nonetheless.

Salmon and sea urchins letting the sperm fly.
Let’s look at where the gametes come from. First the males.

- The male gonads (primary sex organ) are the paired testes (singular testis). Testicle – one testis plus surrounding tissues.
- Human sperm needs to develop 3°C cooler than the rest of the body.
- Therefore, the scrotum has evolved to contain the testes.
- Seminiferous tubules produce the sperm cells.
- Sustenacular cells surround, support, and nourish sperm cells.
- Interstitial cells secrete male sex hormones (mixed gland).
- Ducts get the sperm from the testes out of the body. These are . . .
  - The epididymis – receives and stores sperm from the testes;
  - The vas deferens – connects the epididymis to the . . .
  - Ejaculatory ducts, which empty into the urethra and out the penis.
- Semen includes sperm and secretions from several accessory glands.
  - Seminal vesicles – make most of the fluid, plus sugar for sperm energy, and prostaglandins that may stimulate female contractions.
  - Prostate gland – thin milky fluid that activates sperm to swim.
  - Bulbourethral gland – alkaline mucus to coat the urethra.
All of that in one penis (and nearby). Wow.

Obviously, not erect!

No baculum, no ‘regular’ muscle!

- Vas deferens (2) carries sperm to the urethra.
- Ureter (1 of 2) from kidney
- Seminal vesicle (1 of 2) secretes a fructose-rich fluid that is the main component of semen.
- Ejaculatory duct (1 of 2) connects the vas deferens with the urethra.
- Rectum (digestive tract)
- Prostate secretes an alkaline fluid that helps activate sperm.
- Bulbourethral gland (1 of 2) secretes fluid that helps neutralize acid in residual urine.
- Anus (digestive tract)
- Epididymis (1 of 2) stores sperm as they finish maturing.

- Penis is part of the urinary and reproductive systems.
- Erectile tissue: The penis has three cylinders of erectile tissue.
- Urethra carries semen and urine out of the body.
- Prepuce (foreskin) covers the glans penis; may be removed by circumcision.

Wednesday, April 20, 2011
And it’s got four main tissue types. Again, ho hum . . . .

<table>
<thead>
<tr>
<th>Main tissue types</th>
<th>Examples of Locations/Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epithelial</td>
<td>Lines ducts of reproductive tract; produces sperm cells in seminiferous tubules; produces secretions in accessory glands</td>
</tr>
<tr>
<td>Connective</td>
<td>Makes up walls of testes; makes up erectile cylinders in penis</td>
</tr>
<tr>
<td>Nervous</td>
<td>Penis contains sensory nerve fibers and nerve endings; hypothalamus secretes hormones that affect the anterior pituitary</td>
</tr>
<tr>
<td>Muscle</td>
<td>Smooth muscle surrounds ducts of reproductive tract, propelling sperm out of the body</td>
</tr>
</tbody>
</table>
Spermatogenesis is the production of sperm.

- It begins at puberty and extends throughout life.
- Spermatogonia – are diploid germ stem cells. These...
- Divide mitotically – one daughter remains a germ cell, the other becomes a diploid primary spermatocyte, which undergoes the...
- First round of meiosis to produce the secondary spermatocyte.
- Spermatids – four haploid cells per primary spermatocyte – are produced at the end of meiosis.
Here's a diagram of the process.
But they're not quite sperm yet. They need to complete differentiation into spermatozoa for that.

- They develop tails for the big swim.
- They lose much of their cytoplasm.
- The DNA is all packaged into their head.
- Mitochondria migrate to a collar around the tail just below the head. (This is why mtDNA is only inherited from your mother, since only the head penetrates the egg.) These will generate energy for the big swim. And the...
- Acrosome makes enzymes to pierce the egg.
Here's an animation of spermatogenesis.

http://www.valdosta.edu/~stthompson/animations/Chapter37/Spermatogenesis.swf
And what they look like, up close and personal.
As we saw earlier, hormones are involved in the process.

- The hypothalamus secretes gonadotropin releasing hormone (GnRH). This ...
- Stimulates the anterior pituitary to release ...
- Follicle-stimulating hormone (FSH) – which allows testosterone to stimulate sperm production, sustain libido (psychological sex drive), and produce secondary sexual characteristics (beard, etc.) – and ...
- Luteinizing hormone (LH) – which signals interstitial cells in the testes to release testosterone. It’s all under ...
- A negative feedback control. Where ...
- Inhibin produced by sustenacular cells blocks FSH release.
On to the female side of the story.

- Ovaries are the paired female gonads that produce gametes and sex hormones (mixed organ).
- Approximately once a month (on average, every 28 days), beginning at puberty, the single most mature oocyte is released and...
- Swept into one of the uterine tubes – fertilization usually occurs here.
- The oocyte or zygote (if it’s fertilized) is swept down to the uterus.
- The endometrium lining of the uterus is shed in menstruation, if there is no fertilization. If fertilization occurred, implantation occurs here.
- The cervix is the neck-like opening of the uterus to the vagina.
- The vagina is the receiving organ for the penis during copulation, and also the birth canal. It has an extensive resident microbe population that prevents harmful microorganisms from colonizing (this is why sometimes a heavy antibiotic regime will cause a yeast infection).
- The vulva is the external female genitalia. It consists of the...
- Labia majora and labia minora, which help protect the vaginal opening from external harm, and the...
- Clitoris, which is important for the female orgasm (which makes sex fun).
- Breasts contain fatty tissue, collagen, and milk ducts for breast-feeding.
Here are the parts in a cut-away diagram.

- **Uterus**: Site where embryo develops
- **Uterine tube**: (1 of 2) carries oocyte to uterus.
- **Ovary**: (1 of 2) The paired ovaries produce oocytes and hormones.
- **Cervix**: The end of the uterus that opens to the vagina
- **Rectum**: (digestive tract)
- **Vagina**: Site for sperm delivery; birth canal
- **Vaginal orifice**
- **Clitoris**: Sensitive site of sexual stimulation
- **Cartilage**
- **Urethra**
- **Urinary bladder**
- **Labia minora**
- **Labia majora**
- **Anus**: (digestive tract)
And the female reproductive system consists of the same four main tissue types as the male’s. Again, no big deal...

<table>
<thead>
<tr>
<th>Main tissue types</th>
<th>Examples of Locations/Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epithelial</td>
<td>Lines uterus, uterine tubes, and vagina; produces oocytes in ovaries; forms external surface of umbilical cord</td>
</tr>
<tr>
<td>Connective</td>
<td>Makes up walls of ovaries, uterus, and vagina</td>
</tr>
<tr>
<td>Nervous</td>
<td>Clitoris contains sensory nerve fibers and nerve endings; hypothalamus secretes hormones that affect the anterior pituitary</td>
</tr>
<tr>
<td>Muscle</td>
<td>Smooth muscle surrounds uterine tubes, uterus, and vagina</td>
</tr>
</tbody>
</table>
Oogenesis is the production and development of the egg.

- Oogonium is the female diploid germ stem cell. They...
- Divide mitotically to produce primary oocytes.
- This happens before birth. And meiosis also starts before birth in all of these primary oocytes, but it is...
- Arrested in prophase I of the process.
- At puberty meiosis resumes in one or a few primary oocytes every 28 days or so. The meiotic I division...
- Unequally splits up the cytoplasm yielding one small haploid polar body (not able to be fertilized) and one larger haploid secondary oocyte.
- If a sperm head penetrates, meiosis II is initiated, and the first polar body may again divide, or it may dissolve. Regardless, the secondary oocyte again divides unequally making another polar body, and the mature haploid egg (the ovum). Then the male and female nuclei combine to form the diploid zygote.
- If fertilization does not occur, the oocyte is expelled with the menses.
Here’s the diagram for that.
### Compare and contrast...

<table>
<thead>
<tr>
<th>Prenatal</th>
<th>Birth</th>
<th>Puberty</th>
<th>Fertilization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oogenesis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oogonium</td>
<td>Primary oocytes</td>
<td>Primary oocyte</td>
<td>Secondary oocyte (ovulated)</td>
</tr>
<tr>
<td>Oogonia divide mitotically and produce primary oocytes.</td>
<td>Three months after conception, the ovaries contain two million oocytes, arrested in prophase I.</td>
<td>One or a few oocytes complete meiosis I every month at ovulation.</td>
<td>Meiosis arrested in metaphase II.</td>
</tr>
<tr>
<td><strong>Spermatogenesis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spermatogonium</td>
<td>Spermatogonium</td>
<td>Primary spermatocyte</td>
<td>Secondary spermatocytes</td>
</tr>
<tr>
<td>Spermatogonia begin dividing mitotically.</td>
<td>Spermatids</td>
<td>Sperm are produced in the human male from puberty throughout adult life.</td>
<td>Fertilized egg cell (zygote)</td>
</tr>
</tbody>
</table>

When ovulated secondary oocyte is fertilized in uterine tube, meiosis completes. Otherwise, the oocyte degrades.
And again . . .

Table 37.1  Spermatogenesis and Oogenesis Compared

<table>
<thead>
<tr>
<th>Diploid Starting Cell</th>
<th>Product of Mitosis (Diploid)</th>
<th>Products of Meiosis I (Haploid)</th>
<th>Products of Meiosis II (Haploid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spermatogonium in seminiferous tubule</td>
<td>Primary spermatocyte</td>
<td>Two secondary spermatocytes</td>
<td>Four equal-sized spermatids</td>
</tr>
<tr>
<td>Oogonium in ovary</td>
<td>Primary oocyte</td>
<td>One large secondary oocyte + one small polar body</td>
<td>One large egg cell + three small polar bodies</td>
</tr>
</tbody>
</table>
Of course hormones have a lot to do with this as well!

- There are two interrelated cycles:
  1) Ovarian cycle - controls the timing of oocyte maturation in the ovaries.
  2) Menstrual cycle - prepares the uterus for pregnancy.

- Day one of the menstrual cycle has low blood levels of estrogen and progesterone. This signals the hypothalamus to secrete GnRH (the same hormone as in males).
- GnRH triggers the anterior pituitary to release...
- FSH (just like in males) - which promotes follicle development.
- LH (again the same one as in males) - surges, which triggers ovulation.
- The corpus luteum secretes progesterone and estrogen; this promotes a thickening of the endometrium, and inhibits GnRH, LH, and FSH.
- If no embryo implants, the corpus luteum degrades, progesterone and estrogen levels fall, the endometrium is shed, and inhibition of GnRH, LH, and FSH is turned off. Then the whole cycle starts afresh.
**Table 37.2** The Roles of GnRH, FSH, and LH in Human Males and Females

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Released from:</th>
<th>Acts on:</th>
<th>Function in males</th>
<th>Function in females</th>
</tr>
</thead>
<tbody>
<tr>
<td>GnRH (gonadotropin-releasing hormone)</td>
<td>Hypothalamus</td>
<td>Anterior pituitary</td>
<td>Secreted at constant frequency; stimulates release of LH and FSH</td>
<td>Amount secreted depends on stage of menstrual cycle; stimulates release of LH and FSH</td>
</tr>
<tr>
<td>LH (luteinizing hormone)</td>
<td>Anterior pituitary</td>
<td>Testes, ovaries</td>
<td>Stimulates production of testosterone</td>
<td>Stimulates production of androgens and estrogens; LH surge midway through menstrual cycle triggers ovulation; LH stimulates development of corpus luteum, which secretes progesterone</td>
</tr>
<tr>
<td>FSH (follicle-stimulating hormone)</td>
<td>Anterior pituitary</td>
<td>Testes, ovaries</td>
<td>Enhances production of androgen-binding protein; required for spermatogenesis</td>
<td>Stimulates follicle maturation</td>
</tr>
</tbody>
</table>
The hypothalamus runs the show.

Hypothalamus

GnRH

Pituitary gland

Estrogen and progesterone inhibit the production of FSH and LH

FSH and LH

Ovary

FSH and LH stimulate oocyte maturation

a.
Here's an animation of this hormonal control.

http://www.valdosta.edu/~stthompson/animations/Chapter37/PosNegFeedback.swf
The ovarian cycle regulates follicle maturation and ovulation.
And the menstrual cycle controls the thickness of the endometrium.
Unfortunately, in last semester’s optional essay, a lot of people . . .

Claimed that ovulation occurs two to three days before and (or) after your menstrual period.

This is blatantly not true, and may partially explain why there are so many teen pregnancies! I have no idea where this idea is coming from, but one woman even claimed her doctor told her. How can such a pernicious lie be so widely held?

As the diagram shows, ovulation occurs mid-cycle, on approximately day 14. That is about a week and half to two weeks after your menstrual flow stops, not just a few days after (or before)!
Here's another graph, this one from Wikipedia:

There are many ways to interrupt the ‘natural’ way of things with various birth control strategies.
After fertilization - development.

- First off - the sperm must penetrate the egg to fertilize.
- And the egg has a layer of proteins and carbohydrates, .
- Plus a layer of follicular cells around the outside of it.
- The sperm uses digestive enzymes in the acrosome to get through these layers.
- When the membrane of one sperm touches the secondary oocyte it induces a series of reactions such that the .
- Oocyte surface changes so no other sperm can enter.
- Then the oocyte completes meiosis, and the .
- Two nuclei fuse to become the diploid zygote.
- Ovulation of two separate eggs fertilized by two separate sperms results in fraternal (nonidentical) twins.
The preembryonic stage is the...

* First two weeks of prenatal development.
* The zygote begins a period of rapid mitotic division called cleavage. The first stage is called the...
* Morula – a solid ball of 16 or more cells. Then the...
* Blastocyst – a ball hollows out, its center fills with fluid.
* The outer layer – the trophoblast – forms the fetal portion of the placenta.
* The inner cell mass will develop into the embryo.
* Implantation – the blastocyst burrows into the uterine lining.
* Trophoblast cells secrete human chorionic gonadotropin (hCG) – this keeps the corpus luteum cranking out progesterone, which prevents menstruation. It does this for about ten weeks.
Here's that first week.

Uterine tube, Zygote, Fertilization, Ovulated secondary oocyte, Ovary, Muscle layer, Endometrium, Trophoblast, Inner cell mass, Blastocyst implants, Day 1, Day 2, Day 3, Day 7.
Implantation...

* The blastocyst completes implantation during the second week of development.
* The inner cell mass changes:
  * The amniotic cavity forms within the amnion.
  * The inner cell mass flattens into a two-layered embryonic disc consisting of ectoderm and endoderm. Then a...
  * Middle layer of mesoderm forms. This is the...
* Gastrula, with its characteristic three primary germ layers (remember – endoderm, mesoderm, ectoderm).
* Gastrulation marks the end of the preembryonic stage.
* The preembryo may split early in development to form identical twins – conjoined twins do not separate completely.
Here's that time between the first and second week – implantation and gastrulation.
The embryonic stage is the...

- End of the second week up through the eighth week.
- Cells of the three primary germ layers divide and differentiate to form all of the body's organs.
- There are four extraembryonic membranes:
  1) **Yolk sac** – makes the first blood cells (until about week six), and parts of it develop into the embryo's intestines and germ cells.
  2) **Allantois** – also manufactures blood cells, and gives rise to the blood vessels of the umbilical cord.
  3) **Amnion** – sac containing protective amniotic fluid.
  4) **Chorion** – outermost layer – chorionic villi extend into the uterine lining establishing the beginning of the placenta.
- **Placenta** – one side is embryonic, the other side has mother's blood. This is very, very important...
- It exchanges oxygen and nutrients for waste products.
- The umbilical cord connects the embryo to the placenta.
Important changes during the first half of the embryonic stage lead to the formation of the placenta.
During third week of...

- Prenatal development distinct organs form in the embryo.
- The ectoderm becomes the nervous system, sense organs, outer skin layers, hair, nails, and skin glands.
- The mesoderm forms the coelom with the chest and abdominal cavities.
- Endoderm cells form the organs and linings of the digestive and respiratory systems.
- A furrow called the "primitive streak" appears along the back of the embryonic disc.
- This creates a longitudinal axis laying down the plan for other structures to form along. For example, the...
- Notochord forms, which induces creation of the neural tube, which develops into the brain and spinal cord.
Major differentiation is induced between the second and fourth week. For example, the primitive streak becomes the notochord, which induces the formation of the neural groove, which eventually becomes the spinal cord and brain.
During the fourth week of embryonic development . . .

* Blood cells appear and fill developing blood vessels;
* Immature lungs and kidneys appear; and . . .
* Limb buds appear that will form arms and legs.
* The embryo is about 6 mm (1/4 inch) long now.

During the fifth week, the . . .

* Embryo’s head is very large, comparatively;
* The limbs grow ending in plate-like structures;
* Then cells die to form separate fingers and toes;
* The brain is rapidly forming and the eyes open.
All embryos have unspecialized reproductive structures.

- As discussed earlier in the semester . . .
- The SRY gene on the Y chromosome is activated in males, which begins an entire cascade of events leading to 'maleness.'
- This happens during week seven.
- Hormones stimulate the development of the male reproductive organs and glands.
- No SRY gene results in female structures.
Sexual determination is initiated by SRY.

The following slide is from my earlier talk on human genetics. It gives some great resources on this topic.
There are some great Internet resources related to human sex determination.

* I wrote a sample manuscript for a comparative genomics course I taught a few years back: http://www.bio.fsu.edu/~stevet/CompGen/SRY.manuscript.pdf.

* The Howard Hughes Medical Institute has a wonderful sight named “Biointeractive” that has a sex determination module: http://www.hhmi.org/biointeractive/gender/index.html.

* The Annenberg Foundation’s “Rediscovering Biology” has a unit on it: http://www.learner.org/courses/biology/units/gender/index.html. We watched their video earlier in the semester.

* The premier British science journal Nature has a special focus on the Y chromosome: http://www.nature.com/nature/focus/ychromosome/.

* And Jonathan Wolfe has a very nice lecture on the topic: http://www.ucl.ac.uk/~ucbhjow/b250/sex_determination.html.
Anyway, back to embryology. The fetal period is the...

- Beginning of ninth week to the full 38 weeks of development.
- The fetus grows considerably.
- Organs begin to function and coordinate.
- Bones begin to form, replacing cartilage.
- Nerves coordinate and limbs move.
- During the final weeks:
  - The digestive and respiratory systems mature last. Therefore, premature infants often have digestive and/or respiratory problems.
The placenta is completely formed by the thirteenth week.
Nine weeks, 14 weeks, 16 weeks, and 7 months of gestation
In review...

Table 37.4  Stages in Development from Conception to Birth

<table>
<thead>
<tr>
<th>Name</th>
<th>Duration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zygote</td>
<td>About 24 hours after ovulation</td>
<td>Fertilized egg cell</td>
</tr>
<tr>
<td>Preembryonic stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morula</td>
<td>3–4 days after fertilization</td>
<td>Solid ball of 16 or more cells</td>
</tr>
<tr>
<td>Blastocyst</td>
<td>4 days to 2 weeks after fertilization</td>
<td>Hollow sphere consisting of outer layer (trophoblast) and inner cell mass; implants into endometrium</td>
</tr>
<tr>
<td>Gastrula</td>
<td>2 weeks after fertilization</td>
<td>Three germ layers form: endoderm, mesoderm, ectoderm</td>
</tr>
<tr>
<td>Embryonic stage</td>
<td>From implantation until about 8 weeks after fertilization</td>
<td>Germ layers differentiate into organ systems</td>
</tr>
<tr>
<td>Fetal stage</td>
<td>From end of eighth week until birth (end of first trimester, plus second and third trimesters)</td>
<td>Organ systems become functional</td>
</tr>
</tbody>
</table>

And a beautiful video of human development from conception through early childhood: [http://www.youtube.com/watch?v=jvanNDQhlYI](http://www.youtube.com/watch?v=jvanNDQhlYI)

Wednesday, April 20, 2011
Time for birth . . . labor!

1) During the first stage of labor . . .
   * Hormones increase the frequency and intensity of smooth muscle contractions.
   * And the cervix stretches to about 10 cm.

2) During the second stage, the . . .
   * Baby descends through the cervix, crowns, and then passes out the vagina.

3) And during the third stage, the . . .
   * Uterus expels the placenta.
Here are those stages of labor.

Birth defects are . . .

- Any abnormality that causes the death or disability of a child.
- They can be caused by chromosomal abnormalities, e.g. . . .
- Extra copies of chromosome 21 cause Downs syndrome.
- Genetic defects such as point mutations can cause them too, (remember OMIM at NCBI) e.g. . . .
- Tay-Sachs, phenylketonuria, and other metabolic disorders.
- And teratogens are substances that cause birth defects, e.g. . . .
- Thalidomide was given in the late ’50’s to treat morning sickness, but it was discovered that it caused severe limb shortening.
- Alcohol, cigarettes, and other prescription and nonprescription drugs, excess or insufficient vitamins, starvation, and viral infection can all cause birth defects.
- The “critical period” of a structure is the time during which its development is most susceptible to damage.
- Developing organs are particularly sensitive during the embryonic stage.
Here's when different systems are particularly vulnerable.
And an animation of the same sort of thing.

http://www.valdosta.edu/~stthompson/animations/Chapter37/fetal_development.swf
Remember —

Exam IV next time! Don’t stress over all the details. With this much material, the exam will only be over the biggest, most important, general concepts, of all this animal physiology stuff.