You started off, as did all humans (as does, indeed, all life on Earth) very small. You are the result of the chance meeting and fusing of two cells. The human reproductive system is the system which produces specialized cells capable of combining their genetic information to form a new individual. This requires special organs and structures for producing these special cells, for bringing the cells close enough together so that they can fuse, and for providing a place for the new individual to develop into a viable human being. The processes also require the coordination of various hormones. In this chapter, we will learn about the structures, processes and functions of the human reproductive system.

Male Reproductive System
TESTES

The testes (sometimes still called “testicles” Testes actually comes from the Latin word meaning “witness”)

Testes are paired organs that develop from gonads within abdomen of fetus. They subsequently descend through a canal into scrotal sacs (a pouch of skin located below the pelvic region) during the last 2 months of fetal development.

SCROTUM maintains testes at cooler temperature than the abdominal cavity. This is necessary for producing viable sperm. Sterility, due to too high body temperature, results if testes fail to descend; can be corrected by surgery.

SEMINIFEROUS TUBULES are coiled tubules packed into lobes of the testes that produce sperm. Inside the seminiferous tubules are other cells called SERTOLI CELLS that nourish the developing sperm cells.

INTERSTITIAL CELLS (also known as Leydig cells) in the testes surround the seminiferous tubules and produce the male hormone TESTOSTERONE.

SPERM – the male gamete

- Men can produce up to 1,000,000,000 sperm per day. The whole process of spermatogenesis takes about 9 or 10 weeks.
- Produced inside SEMINIFEROUS TUBULES in testes. Testes contains sections called lobules, each with one to three coiled seminiferous tubules with total length of 250 meters.
- Sperm mature and are stored in the tubular EPIDIDYMIDES (singular = EPIDIDYMIS) behind each testes.
- Once mature, sperm propelled into VAS DEFERENS by muscle contractions.
- Sperm moves from storage in vas deferens to urethra for ejaculation.

- Sperm is composed of three parts: HEAD, MIDDLE PIECE, and TAIL.
- In the middle piece are numerous MITOCHONDRIA which provide energy for sperm movement.
- Middle piece and tail have microtubules with 9 + 2 pattern of cilia and flagella.
- On the tip of the head is the ACROSOME CAP. The acrosome cap contains ENZYMES needed to penetrate the outer barriers of the egg.
- Normal male releases over 100 million sperm per ejaculation; usually, fewer than 100 reach vicinity of egg; one penetrates. An egg is actually 100,000 times larger than a sperm.
- SPERMATOGENESIS is development of sperm; involves meiosis (cell division that reduces the number of chromosomes by half).
- SUSTENTACULAR (SERTOLI) CELLS are other cells inside the seminiferous tubules that support, nourish and regulate the cells that generate sperm cells.
**PENIS**
- the penis is a cylindrical-shaped organ in that hangs in front of scrotum.
- **Spongy tissue** inside shaft of penis is flaccid (soft) with normal blood flow in the penis.
- ERECTION occurs from increased blood flow filling spongy tissue.
- IMPOTENCY is failure to become erect.

**SEmen**
- Semen is a thick, whitish fluid containing SPERM and SECRETIONS FROM THREE ORGANS.
  - i) SEMINAL VESICLES: Two seminal vesicles join two vas deferens; secrete NUTRIENTS FOR SPERM at time of ejaculation.
  - Ejaculatory duct is single duct leading from two vas deferens; carries semen to urethra.
  - ii) PROSTATE GLAND surrounds urethra below bladder; secretes milky alkaline fluid that aids sperm motility and survival (helps to neutralize the acidic environment in the vagina).
  - Prostate gland enlargement is common in older men; constricts urethra and makes urination difficult. (Prostate cancer is 3rd largest cancer killer of men.)
  - iii) BULBOURETHRAL GLANDS (often called COWPER'S Glands) have mucous secretions with LUBRICATING EFFECT.
  - note that the urethra also carries urine from the bladder during urination.

**Ejaculation**
- a process in which semen is forced from the penis
- sexual arousal can cause an erection, and ejaculation occurs when sexual arousal reaches its peak.
- after sperm enters the ejaculatory duct, the seminal vesicles, prostate gland, and Cowper's gland release their secretions.
- Rhythmic contractions of the ejaculatory duct and urethra expels semen from the penis. This (and accompanying physiological and psychological sensations) is known as male orgasm.
- "Refractory period" is typical time following ejaculation during which erection cannot occur. This time tends to increase as a man ages.

**Testes Also Produce Hormones**
- hormones and negative feedback cycles control the development and maintenance of the male reproductive system. After puberty, a man maintains a relatively constant level of testosterone and sperm production. Let's look at the feedback loops involved. There are four hormones involved: GnRH, FSH, LH (also called ICSH), and Inhibin.
- **HYPOTHALAMUS** ultimately controls testes by secreting GONADOTROPIC-RELEASING HORMONE (GnRH).
- GnRH triggers **ANTERIOR PITUITARY** to produce two hormones: FSH and ICSH.
- **FOLLICLE-STIMULATING HORMONE (FSH)** is released by the anterior pituitary. FSH promotes spermatogenesis in seminiferous tubules. It does this
by entering the Sertoli cells and causing them to take up more testosterone. This in, turn, enhances sperm production.

- As sperm is made, Sertoli cells in the seminiferous tubules also release hormone **INHIBIN**. The more sperm that is made, the more inhibin is released. Since inhibin is a hormone that travels in the blood and can be detected by the brain, inhibin levels in the blood are the body’s way of keeping track of sperm levels. As inhibin (and therefore sperm) levels rise, this is detected by the hypothalamus and anterior pituitary gland. The hypothalamus and anterior pituitary in turn, **reduce the release of GnRH and FSH**, which in turn reduces the amount of sperm and inhibin being released. This is a classic **negative feedback cycle**.

- **INTERSTITIAL CELL-STIMULATING HORMONE (ICSH)** (called **luteinizing hormone (LH)** in females), **controls production of testosterone by interstitial cells**. LH thus causes increased testosterone levels in the blood. High levels of LH is detected by the hypothalamus, which then reduces its release of GnRH – another **negative feedback loop**!

- Interaction of hormones maintains **fairly constant production** of sperm and testosterone.

**TESTOSTERONE is the Male Sex Hormone**

- Promotes normal **development** and **function** of **primary sexual organs** of male. (e.g. high levels of testosterone in puberty stimulate the maturation of the penis & testes). Causes **development of secondary sexual characteristics** during puberty (beard growth, axillary & pubic hair), deepens voice, greater muscle growth)

- Testosterone is necessary for the **development of sperm** (FSH causes spermatogenic cells in testes to take up testosterone -- testosterone causes these cells to produce sperm).

- Testosterone **increases secretions** from oil and sweat glands (contributes to acne and body odor).

- Side effect of **baldness** (which is also controlled by genetic factors).

- **Aggressiveness** and aggressive behavior is testosterone related.

- **Sex drive** is also related to testosterone levels. Indeed, testosterone is administered to people (male or female!) who complain of a low sex drive.

- Since testosterone causes an increase in muscle mass, athletes have used testosterone and other “anabolic steroids” to artificially boost their body’s natural male hormone levels. However, anabolic steroids have **serious negative side effects**.

**Summary of Male Reproductive System Parts**

<table>
<thead>
<tr>
<th>Structure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testes</td>
<td>Produce sperm cells and male sex hormones (i.e. testosterone)</td>
</tr>
<tr>
<td>Seminiferous Tubules</td>
<td>Produce immature sperm cells.</td>
</tr>
<tr>
<td>Epididymis</td>
<td>Matures and stores sperm cells in coiled tubules.</td>
</tr>
<tr>
<td>Vas deferens</td>
<td>Carries sperm from the epididymis to its junction with the urethra.</td>
</tr>
<tr>
<td>Seminal vesicles</td>
<td>Secretes fructose into the semen which provides energy for the sperm.</td>
</tr>
<tr>
<td>Prostate Gland</td>
<td>Secretes an alkaline buffer into the semen to protect the sperm from the acidic environment of the vagina.</td>
</tr>
<tr>
<td>Cowper's Glands (Bulbourethral glands)</td>
<td>Secretes mucus-rich fluids into the semen that protect the sperm from acids in the urethra</td>
</tr>
<tr>
<td>Penis</td>
<td>Deposits sperm into the vagina during ejaculation.</td>
</tr>
</tbody>
</table>

You should be able to **trace the path of a sperm cell through all the structures of the male reproductive system**.

**FEMALE REPRODUCTIVE SYSTEM**

**Overview**

- The female reproductive system is designed for the production of the female gamete (the ovum) as well as for receiving the male gamete, and for providing a suitable environment for the development of a new human life. Over the course of 28 days each month after puberty, the body of a female undergoes a regular cycle of events, known as the **menstrual cycle**, that accomplishes these goals.

- First, let’s review the parts of the female system.
• **OVARIES** are two egg-shaped are to each side of uterus in pelvic abdominal cavity. The ovaries *produce eggs* (ova) and the *sex hormones* estrogen & progesterone.

• Each ovary measures about 3 cm by 1 cm in size. Are held in place by ligaments to oviduct and uterus.

• Each month, an ovary produces an egg that bursts from ovary during *ovulation*. Release of oocyte (egg) is called **OVULATION**.

• Ovaries contain **FOLLICLES** containing oocyte plus surrounding **FOLLICLE CELLS**.

• Female is born with up to 2 million follicles; reduced to about 350,000 - 400,000 at puberty; **only about 400 mature** at about one egg per month in reproductive life of average woman.

• **OVIDUCTS** are tubes to the uterus, and extend from near ovaries into uterus. Oviducts sweep up eggs from ovary using cilia lining and wafting *fimbriae* at end of oviducts.

• Fimbriae are fingerlike ends of the oviducts. *Muscular contractions* and cilia lining the oviducts waft the egg toward uterus.

• The **oviducts conduct egg to uterus**. They are also the *site of fertilization*. Sperm usually meet and fertilize an ovum in the upper oviduct. **Mark this on your diagram.** ("Tubular pregnancies" occur when embryo implants in oviduct. *Ectopic pregnancy* is any implantation outside central body of uterus).

• **UTERUS** is thick-walled muscular, hollow, pear-shaped organ for nurturing embryo (fetus develops here); opening in cervix leads to vagina.

• The uterus is about the size and shape of inverted, flattened pear. It lies above and slants forward over the bladder. It can stretches from 5 cm wide to over 30 cm with growing baby.

• The lining of the uterus is called the **ENDOMETRIUM**. The endometrium is composed of connective tissue, glands, and blood vessels. The endometrium lines the uterus and, if pregnancy occurs, forms the **placenta**. The endometrium has a **basal layer** and a **functional layer** that varies with the "uterine cycle."

• A "**Hysterectomy**" is the name for the surgical removal of the uterus.
- **CERVIX** is located at back of vaginal canal. The cervix contains opening to uterus.
- **VAGINA** is a muscular tube with mucosa lining; It makes 45° degree angle with small of back. The vagina serves in intercourse (receives penis during sexual intercourse) and serves as the birth canal during childbirth.
- The external genitals are collectively known as the vulva. **Mons pubis** is fatty prominence under pubic hair. There are two sets of skin folds called labia. Outermost are a pair of fat-padded skin folds called the labia majora, which enclose a smaller pair of skin folds called the labia minora. The labia minora extend from vaginal opening to encircle clitoris at front.
- **CLITORIS** is an erectile organ, partly enclosed by the labia minora, that is sensitive to stimulation. The clitoris is homologous to the male’s penis, and has a shaft of erectile tissue capped by a pea-shaped gland. It has many sensory nerve receptors which makes it sexually sensitive and is prominent in the processes of female orgasm.
- The **hymen** is a ring of tissue that may partially close the vaginal opening. If unbroken as a child it is broken by the first sexual intercourse.

**FEMALE HORMONES & THE MENSTRUAL CYCLE**

- First of all, in order to understand the 28 day menstrual cycle, you need to keep track of what is going on with hormone secretion, the uterus, and the ovaries simultaneously. We will look at the cycle from a locational point of view by studying the uterine cycle and the ovarian cycle. We will look at the cycle from a temporal point of view (i.e. the timing of events) by keeping track of what happens before ovulation (called the follicular phase) and what happens after ovulation (called the luteal phase).
- You can look at the menstrual cycle like a symphony, with all the players doing their part as part of a highly choreographed “dance” involving hormones and feedback cycles. It’s customary to number the days of the menstrual cycle, which lasts on average 28 days. **Day 1** is the first day that menstruation starts.
- During menstruation, some of the uterine lining, plus a small amount of blood, is shed. However, menstruation is only one event in the menstrual cycle. Let’s look first at the ovarian cycle.
- The menstrual cycle can be divided into two main phases: the **FOLLICULAR PHASE** (when a follicle is developing in an ovary), and the **LUTEAL PHASE** (when a follicle has release its egg and is called the corpus luteum).
- In both phases, we need to keep track of hormones, and what is going on in both the ovaries and the uterus. **It’s quite a production!**

**THE FOLLICULAR PHASE: DAYS 1 - 14**

*The Highlights!*
- **Menstruation occurs**, following by a rebuilding of the uterine lining.
- **Increased levels of female hormones** follow menstruation.
- **Estrogen predominates**.
- An “**LH surge**” causes ovulation on **day 14**.
The Details!

- In the uterus between days 1 and 5, the low levels of female hormones (estrogen, progesterone, FSH, LH, GnRH) cause menstruation. In menstruation, part of the lining of the uterus, plus a small amount of blood, is released through the vagina. The lining of the uterus (also called the endometrium) is at its thinnest at this point.
- While this is going on, the female reproductive system is getting ready to repeat the whole cycle once more. The low levels of female hormones is detected by the hypothalamus, causing it to release GnRH. GnRH is sent to the anterior pituitary gland. Remember that GnRH acts on the anterior pituitary gland, making it release the hormones FSH and LH.
- During days 6 to 13, we see increasing levels of FSH and LH. Follow along carefully, because FSH and LH cause different things to happen!
- FSH stimulates follicle development in the ovary, so as the anterior pituitary gland releases increasing amounts of FSH, this makes a follicle mature and get bigger.
- Follicles produce the hormone estrogen, so as the follicle matures and gets bigger, it makes more and more estrogen.
- There is a positive feedback loop involving estrogen, GnRH and LH. As estrogen levels rise, this causes the release of more GnRH, which causes the release of more LH. This is going on between about days 7 to 13. Finally, high levels of estrogen cause the hypothalamus to release a large amount of GnRH, which cause the release of a large amount of LH from the pituitary on day 13. This so-called "LH surge" causes ovulation on day 14. In ovulation, the mature follicle ruptures, releasing the egg from the ovary. The follicle cells stay behind. These remaining follicle cells are called the corpus luteum.
- Meanwhile, the high levels of estrogen also cause negative feedback on the pituitary to reduce the release of FSH, ending the follicular phase.
- In the ovary, the rising levels of estrogen during days 6 - 13 make the uterus lining get thicker. There is a proliferation in the amount of blood vessels and mucus glands in the lining during days 6-13. That's why, in the uterine cycle, this is called the "proliferative phase."

| THE LUTEAL PHASE: DAYS 15 - 28 |

The Highlights!

- Progesterone predominates. It is released by corpus luteum.
- Progesterone makes the endometrium double in thickness and secrete mucus.
- Around about day 25, negative feedback by progesterone on LH causes corpus luteum to start to degenerate, which in turn reduces secretions of progesterone and female hormones, which in turn causes endometrium lining to start to degenerate by about day 28.
- As luteal phase ends, menstruation begins, and we’re back to day 1.

The Details!

- The corpus luteum (the cells left over from the follicle after the egg has been released) produces increasing amounts of progesterone. It is progesterone that predominates in the luteal phase.
- Progesterone makes the endometrium get thicker. It will double in thickness. As the uterine lining is thickening, those mucus glands we mentioned earlier have matured, and begin secreting a thick, mucus material. That’s why this part of the uterine cycle is called the "secretory phase."
- Progesterone levels are controlled by a negative feedback loop. When progesterone levels reach their highest levels, negative feedback to the anterior pituitary gland causes the anterior pituitary gland to release less LH. This happens at around the day 24 or 25 stage.
- Since the corpus luteum requires high levels of LH to maintain itself, as LH levels drop, the corpus luteum begins to degenerate.
- Since it is the corpus luteum that makes progesterone (it also is producing estrogen), as the corpus luteum degenerates, it makes less and less of progesterone (and estrogen).
- Without high levels of progesterone, the endometrium cannot maintain its thickness. It will therefore start to disintegrate by about day 28, and menstruation will once again occur on day 1.
- The whole cycle will continue to repeat itself until pregnancy occurs or the woman goes through menopause. And now, for a one page summary!
<table>
<thead>
<tr>
<th>The Ovarian Cycle</th>
<th>The Uterine Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Low levels of female hormones in blood from days 1 - 5.</td>
<td>• Low levels of female hormones causes <strong>Menstruation</strong> (days 1-5) - endometrium breaks down</td>
</tr>
<tr>
<td>• <strong>FSH levels increase</strong> from days during days 6 - 13.</td>
<td>• Days 6 - 13: the rising levels of estrogen make the <strong>endometrium thicken</strong> and become <strong>vascular &amp; glandular (=proliferative phase)</strong>.</td>
</tr>
<tr>
<td>This causes a <strong>follicle to mature</strong>. As follicle matures, it makes more and more <strong>estrogen</strong>, so <strong>estrogen levels rise</strong>.</td>
<td>• the <strong>endometrium rebuilds</strong> itself.</td>
</tr>
<tr>
<td>• High levels of estrogen in blood causes hypothalamus to secrete a large amount of <strong>GnRH</strong>, which leads to a <strong>LH surge</strong> at day 13 which <strong>causes ovulation at day 14</strong>.</td>
<td></td>
</tr>
<tr>
<td>• <strong>Negative feedback</strong> by <strong>estrogen</strong> on <strong>FSH</strong> ends follicular phase.</td>
<td></td>
</tr>
<tr>
<td>• (days 15 - 28) <strong>Corpus Luteum makes</strong> increasing amounts of <strong>progesterone</strong>.</td>
<td>• (days 15 - 28) <strong>Progesterone makes endometrium double in thickness</strong>.</td>
</tr>
<tr>
<td>• <strong>High progesterone</strong> causes <strong>negative feedback control</strong> over anterior pituitary secretions of <strong>LH</strong>, causing corpus luteum to degenerate.</td>
<td>• <strong>Uterine glands mature</strong> and release thick mucoid secretions.</td>
</tr>
<tr>
<td>• As <strong>luteal phase ends, menstruation occurs</strong>.</td>
<td>• As corpus luteum degenerates, <strong>progesterone secretion decreases</strong>. This causes menstruation to occur again.</td>
</tr>
</tbody>
</table>
And Now, the briefest summary imaginable...

- **Days 1 - 5**: low levels of estrogen and progesterone cause endometrium to disintegrate, blood vessels (menses) rupture and flow out of vagina during **menstruation**.
- **Days 6 - 13**: endometrium becomes thicker and more vascular due to increased amounts of estrogen; called **proliferative phase**.
- **OVULATION** usually occurs on day 14 of 28-day cycle.
- **Days 15 - 28**: endometrium doubles in thickness, uterine glands mature and secrete mucus due to production of progesterone by corpus luteum; readies uterus to receive developing embryo.
- If not pregnant, corpus luteum degenerates; lower hormone levels cause uterine lining to break down.

**Fertilization**

- While several hundred sperm might make it to the egg, only one will fertilize the egg.
- The *acrosome* releases its enzymes which break through the outer layer of the egg. The plasma membranes of the egg and sperm fuse, and the nucleus from the sperm enters the egg. Finally, the sperm nucleus fuses with the egg nucleus. This could correctly be viewed as the moment of **conception**. The new individual at this point is called a *zygote*.
PREGNANCY Follows Fertilization

- Fertilized egg develops as it travels down the oviduct to the uterus.
- Embryo embeds in the endometrial lining (implantation) several days after fertilization.

**If Implantation Occurs...**
- **Implantation** (embryo embedding itself into the endometrium) occurs within a few days of fertilization. Since the developing offspring needs to grow in the uterus undisturbed, the usual menstrual cycle must be interrupted for 9 months.
- Placenta forms from both maternal and fetal tissues: it provides exchange of molecules between fetal and maternal blood.
- Placenta produces **Human Chorionic Gonadotropin (HCG)**, which temporarily maintains the corpus luteum.
- As the placenta develops, it begins to make its own progesterone and estrogen.
- Progesterone and estrogen do two things:
  a) **shut down the release of FSH & LH from the anterior pituitary** (so that no new follicles mature)
  b) maintain the lining of the uterus so that the corpus luteum is not needed.
- There is, of course, **no menstruation during pregnancy**.
Labour and Childbirth

- Fetus rotates with head pointed toward cervix.
- If not in position, breech birth (*rump first*) may require **Cesarean section**.
- End of ninth month, fetus averages 525 mm (20 inches) and 3,380 grams (7.5 pounds).
- **Birth occurs in Stages**
  - Mild, *indiscernible* contractions occur throughout pregnancy; become stronger and more frequent near end of pregnancy
  - true **LABOR** involves *contractions* lasting over 40 seconds occurring every 15 - 20 minutes.