Most systems between males and females in the human body are similar in structure.

The exception of course are the organs of the reproductive system.

Memorable Quote from 'Kindergarten Cop' (1990)

Joseph: Boys have a penis, girls have a vagina!

Detective John Kimble: Thanks for the tip.
Male Karyotype (2n=46)

The differences between males and females are genetically determined and are obviously apparent in the karyotype of an individual.

- 22 pair of autosomal chromosomes
- 1 pair of sex chromosomes

**Males have an X and Y chromosome**

**Females have 2 X chromosomes**

Reproductive System

Function of the differences is to perpetuate the species by means of gamete formation and reproduction

Meiosis

Female parent

Male parent

Eggs

Sperm

XX

XY

Female offspring

Male offspring

XX

XY
Meiosis is the process of producing gametes (sperm and eggs) that have only 23 Chromosomes:

- One from each autosomal pair and
- One from the sex chromosomes.

Homologous chromosomes are pairs of chromosomes with the same arrangement of genes and which we obtained from mother and father. We thus have 23 pairs of homologous chromosomes.

The separation of the chromosomes into the gametes is precise such that one from each pair of homologous chromosomes ends up in a gamete. In addition, crossing over re-arranges some of the genetic information such the unique new combination of genes occurs.

However, which one from each pair ends up in a gamete is complete random. This provides good mixing of maternal and paternal genes into the next generation of gametes (random segregation).
This picture represents a hypothetical case for a species with 6 chromosomes (3 pairs, $2n = 6$). Blue and red colors indicate the parental origin of chromosomes. During metaphase one, crossing over occurs between sister chromatids and pairs of homologous chromosomes are separated.

Meiosis II is where the sister chromatids of each homologous chromosome set is split again into separate daughter cells. This final round thus produces cells with half the number of chromosomes.
Figure 28-6b Chromosomes in Mitosis and Meiosis.

**Meiosis.** The fates of three representative chromosome pairs during the two stages of meiosis.

Chromosomes

Chromosome duplication, synapsis, and tetrad formation

**Meiosis I**

**Meiosis II**

Chromosomes of gametes

Gametes (n)

Reproductive System: Meiosis

1 cell with 2n = 2

4 cells with n = 1
Male Reproductive System

**Major Structures of the Male Reproductive System**
- **Ducts**
  - Ejaculatory duct
  - Membranous urethra
  - Spongy urethra
  - Ductus deferens
  - Epididymis
- **Gonad**
  - Testis
- **External Genitalia**
  - Penis
  - Scrotum

Male Reproductive System

**Accessory Glands**
- Seminal gland
- Prostate gland
- Bulbourethral gland
- Anus

**Additional Structures**
- Prostatic urethra
- Pubic symphysis
- Urinary bladder
- Corpus cavernosum
- Corpus spongiosum
- Rectum
- Ureter
- External urethral orifice
Male Reproductive System

- The Scrotum is a ‘pouch’ that holds the Testes
  - It is covered with skin
  - Is divided into two chambers, or **scrotal cavities**
  - Each testis lies in a separate scrotal chamber

- Tunica Vaginalis
  - Is a serous membrane that lines scrotal cavity
  - Reduces friction between opposing surfaces
  - Deep to this layer is the **Tunica Albuginea**
  - Supports blood and lymphatic vessels of testis and **efferent ductules**

Male Reproductive System

- Temperature Regulation
  - Normal sperm development in testes
    - Requires temperatures 1.1°C (2°F) lower than body temperature
  - Testicular Muscles relax or contract
    - To move testes away or toward body
    - To maintain acceptable testicular temperatures
      - The **Dartos Muscle** (smooth muscle): located in dermis of the scrotum skin
      - **Cremaster Muscle** (skeletal muscle): located deep to the dermis
Male Reproductive System

Septa subdivide testis into lobules. Lobules contain about 800 slender and tightly coiled seminiferous tubules.

Major function of the testis is production of spermatozoans and testosterone, which occurs in and around the seminiferous tubules. The cells that make up the walls of these tubules are the actual site of spermatozoan production.

Spermatozoa move from the tubules into the rete testis, and then via efferent ductules into the epididymis, and into the vas deferens.

The epididymis are the site where immature sperm cells undergo maturation.
Male Reproductive System

Cross section through a seminiferous tubule
Male Reproductive System

(a) Scanning electron micrograph of a cross-sectional view of a seminiferous tubule (225x)

Male Reproductive System

- Organization/Content of Seminiferous Tubules wall
  - Spermatogonia (cells destined for meiosis)
  - Spermatocytes at various stages of meiosis
  - Spermatids
  - Spermatozoa
  - Large nurse cells (also called sustentacular cells or Sertoli cells)
    - Are attached to tubular capsule
    - Extend to lumen between other types of cells
Nurse cells surround the stem cells of the tubule and support the developing spermatocytes and spermatids.

Stages in spermatogenesis in the wall of a seminiferous tubule.
Spermatogenesis is the testicular process in adult males that generates haploid gametes capable of fertilizing ova. The cells destined to undergo meiosis are called spermatogonia.

**Spermatogenesis**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Chromosomes per cell</th>
<th>Chromatids per chromosome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spermatogonia</td>
<td>46</td>
<td>2</td>
</tr>
<tr>
<td>Mitosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary spermatocytes</td>
<td>46</td>
<td>2</td>
</tr>
<tr>
<td>1st meiotic division</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary spermatocytes</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>2nd meiotic division</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spermatids</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>Differentiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spermatozoa</td>
<td>23</td>
<td>1</td>
</tr>
</tbody>
</table>

**Mitosis of spermatogonium**

Each division of a diploid spermatogonium produces two daughter cells. One is a spermatogonium that remains in contact with the basement membrane of the tubule, and the other is a primary spermatocyte that is displaced toward the lumen. These events from spermatogonium to primary spermatocyte take 16 days.
Meiosis I

As meiosis I begins, each primary spermatocyte contains 46 individual chromosomes. At the end of meiosis I, the daughter cells are called **secondary spermatocytes**. Every secondary spermatocyte contains 23 chromosomes, each with a pair of duplicate chromatids. This phase of spermatogenesis takes about 24 days.

Meiosis II

The secondary spermatocytes soon enter meiosis II, which yields four haploid spermatids, each containing 23 chromosomes. For each primary spermatocyte that enters meiosis, four spermatids are produced. This phase lasts only a few hours.

Male Reproductive System

**Spermiogenesis (physical maturation)**

In spermiogenesis, the last step of spermatogenesis, each spermatid matures into a single spermatozoon, or sperm. The process of spermiogenesis—from spermatids to spermatozoa—takes 24 days.

Spermiogenesis

- Is the last step of spermatogenesis
- Each spermatid matures into one spermatozoon (*sperm*)
  - And remains attached to the cytoplasm of nurse cells

At spermiation, a spermatozoon loses attachment to nurse cell and enters the lumen of seminiferous tubule.

It takes about 9 weeks from spermatogonial division to spermiation.
Spermiogenesis: Spermatids to Sperm

- Spermatids lose excess cytoplasm and form a tail, becoming spermatozoa (sperm)
- Major regions of mature sperm
  - Head: genetic region; nucleus and helmetlike acrosome containing hydrolytic enzymes that enable the sperm to penetrate an egg
  - Midpiece: metabolic region; mitochondria
  - Tail: locomotor region; flagellum
Role of Sustentacular Cells (Nurse cells)

• Large supporting cells (Sertoli cells)
• Extend through the wall of the tubule and surround developing cells
• Provide nutrients and signals to dividing cells
• Dispose of excess cytoplasm sloughed off during spermiogenesis
• Secrete testicular fluid into lumen for transport of sperm

Tight junctions divide the wall into two compartments

• Basal compartment—spermatogonia and primary spermatocytes
• Adluminal compartment—meiotically active cells and the tubule lumen

Tight junctions form a blood-testis barrier

• Prevents sperm antigens from escaping into the blood where they would activate the immune system
• Because sperm are not formed until puberty, they are absent during immune system development, and would not be recognized as “self”
Under hot conditions, spermatogenesis is prone to errors, and overheated testes are associated with decreased fertility.

Sertoli cells form tight junctions, preventing the body (blood) to form antibodies against these new “strange” cells.

The “tripartite chain” regulates male reproduction via the Brain-Testicular Axis (the hypothalamic-pituitary-gonadal (HPG) axis):

- GnRH secretion from the hypothalamus drives LH & FSH secretion from the anterior pituitary gland.
- FSH develops the Sertoli cells and prompts them to produce and release Androgen Binding Protein (ABP).
- LH induces Leydig cells to produce testosterone. Leydig cells are the cells between the seminiferous tubules.
In response to follicle stimulating hormone and testosterone, the Sertoli cells support and nourish developing spermatogenesis cells.

Sertoli cells phagocitize debris and secrete testicular fluid, easing the way for new spermatids.

In response to luteinizing hormone, the Leydig cells produce steroids, including testosterone.

Testosterone is needed for proper function of Sertoli cells and maturation of spermatids.

Sertoli cells secrete the hormone INHIBIN.

Sertoli cells produce Androgen Binding Protein, (ABP) facilitating the effects of testosterone.

Male Reproductive System

Testosterone produced by Leydig cells diffuses into the testis area and ABP in Sustenticular (Sertoli)cells binds the testosterone , allowing it to exert its effect.

**Regulation is by means of Negative feedback:**

- Testosterone inhibits GnRH and LH release
- Inhibin is produced when sperm production increases; it keep FSH levels in check as a result of negative feedback.
Male Reproductive System

Testicular androgens exert diverse effects in the reproductive tract, including the promotion of spermatogenesis.

Testicular androgens are also responsible for:
- development of Wolffian ducts and early male characteristics
- development of "male" brain
- transforms boys to men during puberty (stimulates GH secretions and effect)
- In brain, some testosterone is converted into estrogen and determines the libido

Cholesterol

- Progesterone
  - Testosterone
  - Dihydrotestosterone (DHT)
- Corticosterone
  - Cortisol
  - Estradiol
- Aldosterone

Testicular testosterone is converted in peripheral tissues to Dihydrotestosterone (DHT) via alpha-reductase.
**Male Reproductive System**

**TABLE 17-3** Effects of Testosterone in the Male

1. Required for initiation and maintenance of spermatogenesis (acts via Sertoli cells)
2. Decreases GnRH secretion via an action on the hypothalamus
3. Inhibits LH secretion via a direct action on the anterior pituitary
4. Induces differentiation of male accessory reproductive organs and maintains their function
5. Induces male secondary sex characteristics; opposes action of estrogen on breast growth
6. Stimulates protein anabolism, bone growth, and cessation of bone growth
7. Required for sex drive and may enhance aggressive behavior
8. Stimulates erythropoietin secretion by the kidneys

---

**Male Reproductive System**

- Fluid secreted by Sertoli cells assist sperm transport along the lumen of the seminiferous tubules.
- The fluid also generates a pressure that moves the newly formed sperm into the Reti Testis.
- Eventually they end up in the head part of the epididymis
- During passage through epididymis sperm will undergo final maturation process which takes about 14 days; so sperm entering initial part of epididymis is incapable of motility and capacity to fertilize.
Male Reproductive System

- The **Epididymis**
  - Is the start of male reproductive tract
  - Is a coiled tube almost 7 m (23 ft) long
    - Lined with pseudostratified ciliated epithelium
  - Has a **head**, a **body**, and a **tail**

- Three Functions of the Epididymis
  1. *Monitors and adjusts fluid produced by seminiferous tubules*
  2. *Recycles damaged spermatozoa*
  3. *Stores and protects spermatozoa*
     Facilitates functional maturation

![A diagrammatic view of the head, body, and tail of an epididymis](image)
Male Reproductive System

• Spermatozoa Leaving Epididymis into the Vas deferens (Ductus deferens)
  • Are mature, but remain immobile
  • To become *motile* (actively swimming) and functional:
    • Spermatozoa undergo **capacitation**

Two Steps in occur in **Capacitation**
1. Spermatozoa become motile
   When mixed with secretions of seminal glands
2. Spermatozoa become capable of fertilization
   When exposed to female reproductive tract

Male Reproductive System

**Accessory Glands**

• **Seminal Vesicles**:
  • paired pouches located posteriorly at the base of the bladder
  • secretes an alkaline fluid containing fructose, prostaglandins and fibrinogen
  • helps to neutralize the acid environment in the female reproductive tract (sperm is killed by acidic media)
  • fructose provides energy for the mitochondria, fibrinogen makes semen stick and adhere inside the vagina and prostaglandin creates small contractions inside the to propel the sperm along its journey
  • secretions provide about 60% of total seminal fluid
Male Reproductive System

- **Prostate Gland:**
  - a single spherical gland located at base of bladder and encircles the urethra
  - produces a slightly acidic fluid containing citric acid and other sperm activation enzymes such as fibrinolysin
  - makes up 25% of seminal fluid

- **Bulbo-urethral Gland:**
  - paired glands below the prostate gland
  - produce an alkaline fluid as well that neutralizes the acidity of the male urethra

- Sperm count is around 50 - 150 million per ml.
- Sperm count below 50 million/ml reduces fertility chances and if count is lower than 20 million per ml, a male is considered clinically infertile

---

Male Reproductive System

**Causes of abnormal Sperm**

- **Thermal exposure**
  Heat potentially damages spermatogenesis or the sperm that is stored in the epididymis.

- **Testicular surgery**

- **Infections**

- **Radiation**

- **Substance abuse / Medications**

- **Trauma**
Male Reproductive System

**Penis**

- Consist out of 3 cylindrical compartments running length-wise
  - 2 dorsal corpora cavernosa
  - 1 ventral corpus spongiosum

- During sexual stimulation, small arteries feeding these compartments relax and blood floods the compartments causing erection.

**Erection is under Para-sympathetic control**

- Vasoilation is further influenced by nitric oxide (NO)
- NO produces cGMP which in turn causes smooth muscle relaxation

**Ejaculation is under sympathetic control**
Male Reproductive System

Descending CNS pathways triggered by thoughts, emotions, and sensory inputs such as sight and smell

Input from penis mechanoreceptors

Neurons to penis
  ↑ Activity of neurons that release nitric oxide
  ↓ Activity of sympathetic neurons

Penis
  Dilation of arteries
  Erection
  Compression of veins

Nitric Oxide released during sexual stimulation

Activates Guanyl Cyclase

Production of cyclic GMP

Smooth muscle relaxation

Increased blood flow Erection

Viagra (inhibits PDE)

Phosphodiesterase (PDE) (Breaks down cGMP)