Overview of Reproduction

Reproductive System Essentials

- **Gonads** (reproductive organs)
  - Testes in males, ovaries in females
- **Gametes** (reproductive cells)
  - Spermatozoa (*sperm*) in males,
  - Ova (*eggs*) in females
- **Fertilization**
  - Fusion of male and female gamete
- **Zygote**
  - Fertilized egg
Male Reproductive System

Reproductive Organs

• **Testes**
  • Enclosed by *scrotum*
  • Produce *spermatazoa* (sperm)

• **Epididymis**
  • Stores sperm

• **Ductus deferens (vas deferens)**
  • Conducts sperm outward
Male Reproductive System

Reproductive Organs (cont’d)

• *Ejaculatory duct*

• *Accessory organs*
  1. *Seminal vesicle*
  2. *Prostate gland*
  3. *Bulbourethral glands*

• *Urethra*
  • Inside the *penis*, an erectile organ
Male Reproductive System

The Male Reproductive System

- Ureter
- Seminal vesicle
- Prostate gland
- Ejaculatory duct
- Bulbourethral gland
- Urethra
- Penis
- Glans
- Prepuce
- Scrotum
- Ductus deferens
- Epididymis
- Testis
- Urinary bladder
- Rectum
- Pubic symphysis

Figure 19-1
The Testes

- Primary sex organ in males
- Hang within scrotum
- Cremaster muscle lifts testis toward body
- *Tunica albuginea* encloses testis
The Testes (cont’d)

- Septa divide testis into lobules
- Seminiferous tubules within lobule produce sperm
- Interstitial cells surround tubules
  - Produce testosterone, the main male sex hormone
Seminiferous Tubules

- Contain spermatogonia
- Stem cells for spermatogenesis = sperm production
The Scrotum, Testes, and Seminiferous Tubules

- Efferent ductule
- Epididymis
- Ductus deferens
- Rete testis
- Skin
- Dartos muscle
- Cremaster muscle
- Scrotal cavity
- Septa
- Tunica albuginea
- Seminiferous tubule

Figure 19-2(a)
Male Reproductive System

The Scrotum, Testes, and Seminiferous Tubules

Figure 19-2(b)  
Seminiferous tubules containing nearly mature spermatozoa about to be released into the lumen

Seminiferous tubules containing late spermatids

Seminiferous tubules containing early spermatids

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Male Reproductive System

The Scrotum, Testes, and Seminiferous Tubules

- Dividing spermatocytes
- Spermatozoa
- Spermatids
- Spermatogonium
- Interstitial cells
- Capillary
- Sustentacular cell nucleus
Male Reproductive System

Anatomy of a Spermatozoon

1. Head
   • Contains nucleus and chromosomes
   • Acrosomal cap contains enzymes

2. Middle piece
   • Contains mitochondria

3. Tail
   • Whips the sperm along
SPERMATOGENESIS

MITOSIS of spermatogonium (diploid)

Primary spermatocyte (diploid)

DNA replication

MEIOSIS I

Synapsis and tetrad formation

Primary spermatocyte

Tetrad (four chromatids)

Secondary spermatocytes

MEIOSIS II

Spermatids (haploid)

SPERMIOGENESIS (physical maturation)

Spermatozoa (haploid)
SPERMATOGENESIS

MITOSIS of spermatogonium (diploid)

Primary spermatocyte (diploid)
<table>
<thead>
<tr>
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<tr>
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<tr>
<td>DNA replication</td>
</tr>
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<td>MEIOSIS I</td>
</tr>
<tr>
<td>Synapsis and tetrad formation</td>
</tr>
<tr>
<td>→ Primary spermatocyte</td>
</tr>
<tr>
<td>→ Tetrads (four chromatids)</td>
</tr>
<tr>
<td>→ Secondary spermatocytes</td>
</tr>
</tbody>
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MITOSIS of spermatogonium (diploid)

Primary spermatocyte (diploid)

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Synapsis and tetrad formation

Tetrad (four chromatids)

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Tetrad (four chromatids)

Secondary spermatocytes

MEIOSIS II

Spermatids (haploid)

SPERMIOGENESIS (physical maturation)

Spermatozoa (haploid)
Male Reproductive System

Spermatozoon Structure

- Acrosomal cap
- Nucleus
- Mitochondrial spiral
- Cell membrane of flagellum

Head
Neck
Middle piece
Tail (flagellum)

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Figure 19-4
Key Note

Meiosis produces gametes that contain half the number of chromosomes found in somatic cells. For each cell entering meiosis, the testes produce four spermatozoa, whereas the ovaries produce only one ovum.
Male Reproductive System

Male Reproductive Tract

1. Epididymis
   • Long tubule in which sperm mature
   • Sperm learn to swim: “YMCA”

2. Ductus deferens (vas deferens)
   • Carries sperm from epididymis into body cavity
   • Joins with seminal vesicle
   • Forms ejaculatory duct

3. Urethra
   • Extends from bladder to tip of penis
   • Passageway for urine and semen
Male Reproductive System

The Ductus Deferens

Ureter

Ductus deferens

Seminal vesicle

Ejaculatory duct

Prostate gland

Urethra

Bulbourethral gland

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Male Reproductive System

The Ductus Deferens

Figure 19-5(b)

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The Accessory Glands

1. Seminal vesicle
   - Secretes 60% of volume of semen
   - Secretes fructose to power the sperm

2. Prostate gland
   - Contributes about 30% of semen volume
   - Contains antibiotic to prevent UTI’s

3. Bulbourethral glands (Cowper’s gland)
   - Secretes alkaline mucus as a lubricant
Semen

- Typical ejaculation expels 2–5 ml of semen
- Called the *ejaculate*
- Contains 20–50 million sperm per ml
The Penis

• Penis skin resembles scrotal skin
• Contains three *erectile bodies*
  • A pair of *corpora cavernosa* dorsally
  • A single *corpus spongiosum* ventrally
  • Urethra passes through it
• *Erection* of penis follows dilation of erectile bodies with blood
Male Reproductive System

The Penis

- Pubic symphysis
- Body (shaft of penis)
- Root of penis
- Ischial ramus
- Corpus spongiosum
- Corpora cavernosa (erectile tissue)
- Glans
- External urethral meatus
- Scrotum

(a) Anterior and lateral view of penis

Figure 19-6(a)
Male Reproductive System

The Penis

- Ureter
- Trigone of urinary bladder
- Prostate gland
- Urethra
- Opening of duct from bulbourethral gland
- Corpus spongiosum
- Corpora cavernosa
- Urethra
- Glans
- Prepuce
- Seminal vesicle
- Opening of ejaculatory duct
- Ductus deferens
- Bulbourethral gland
- External urethral meatus

(b) Frontal section

Figure 19-6(b)
The Penis

(c) Section through shaft of penis
Hormones and Male Reproductive Function

1. Pituitary Hormones
   - *Follicle-stimulating hormone* (FSH)
     - Promotes spermatogenesis
   - *Luteinizing hormone* (LH)
     - Stimulates testosterone production

2. Gonadotropin Releasing Hormone (GnRH)
   - Hypothalamic hormone controls pituitary

3. Androgens (steroids)
   - *Testosterone* most important
Male Reproductive System

Hormonal Feedback in the Regulation of Male Reproductive Function

Figure 19-7

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Female Reproductive System

Principal Female Reproductive Organs

- Ovaries
- Uterine (Fallopian) tubes
- Uterus
- Vagina
- External genitalia (vulva)
The Ovaries

• Primary sex organs of females
  • Size and shape of almond
  • Site of oogenesis (ovum production)
• Responsible for monthly ovarian cycle
• Responsible for several stages in ovum development
The Ovaries (cont’d)

• Stages in oogenesis (ovum production):
  1. Stem cells (oogonia) complete mitosis before birth
  2. Primary oocytes begin meiosis before birth (stop at prophase) about 2 million of these
  3. They stay in a state of suspended animation until puberty. Only about 400,000 primary oocytes survive until then.
Oogenesis Cont.

4. At puberty the primary follicles begin to mature. It could take up to a year for 1 follicle to mature.
   - follicle contains the oocyte
   - Oocyte is surrounded by special layer of cells

Now the Ovarian Cycle can begin.

- 28 day cycle
- Includes: follicular phase, ovulation, luteal phase
OOGENESIS

MITOSIS of oogonium (before birth)

DNA replication (before birth)

MEIOSIS I begins before birth
Synapsis and tetrad formation

MEIOSIS I completed after puberty

MEIOSIS II begun in the tertiary follicle and completed only if fertilization occurs

If fertilization occurs after ovulation, MEIOSIS II is completed

Primary oocyte (diploid)

First polar body (may not occur)

Secondary oocyte (haploid)

Secondary oocyte ovulated in metaphase of MEIOSIS II

Second polar body

Ovum (haploid)

Maturation of gamete

Figure 19-9
1 of 5
OOGENESIS

MITOSIS of oogonium (before birth)

Primary oocyte (diploid)
OOGENESIS

MITOSIS of oogonium (before birth)

DNA replication (before birth)

MEIOSIS I begins before birth

Synapsis and tetrad formation

Primary oocyte (diploid)

Tetrad

Primary oocyte
OOGENESIS

MITOSIS of oogonium (before birth)

DNA replication (before birth)

MEIOSIS I begins before birth
Synapsis and tetrad formation

MEIOSIS I completed after puberty

Primary oocyte (diploid)

Tetrad

First polar body

Secondary oocyte (haploid)
**OOGENESIS**

- **MITOSIS of oogonium (before birth)**
  - Primary oocyte (diploid)

- **DNA replication (before birth)**
  - Tetrad

- **MEIOSIS I begins before birth**
  - Synapsis and tetrad formation
  - Primary oocyte
  - MEIOSIS I completed after puberty
  - First polar body (may not occur)

- **MEIOSIS II begun in the tertiary follicle and completed only if fertilization occurs**
  - Secondary oocyte (haploid)
  - Secondary oocyte ovulated in metaphase of MEIOSIS II

- **If fertilization occurs after ovulation, MEIOSIS II is completed**
  - Ovum (haploid)
  - Maturation of gamete

---

*Figure 19-9*

5 of 5
Primordial follicles before puberty

Primordial follicles

Follicle cells

Primary oocytes

Zona pellucida

Secondary follicle

Nucleus of primary oocyte

Follicle cells

Zona pellucida

Tertiary follicle

Primary oocyte containing follicular fluid

Zona pellucida

OVULATION

Outer surface of ovary

Released secondary oocyte

Corpus luteum

Degenerating corpus luteum

Corpus luteum

Corona radiata

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Figure 19-10
Primordial follicles before puberty
Figure 19-10

Primordial follicles before puberty

- Primordial follicles
- Follicle cells
- Primary oocytes
- Zona pellucida

Primordial follicles

- Primordial follicles
- Primary follicle
Follicular Phase:

1. At start of Ovarian Cycle, an ovary contains only a few secondary follicles

2. By day 5 there is usually only 1
3. FSH causes the follicle to mature into a tertiary follicle or Graafian follicle

4. This happens 10-14 days into the cycle.
Ovulation:
1. Secondary oocyte bursts out of ovary
2. Generally happens day 14 of 28 day cycle.
Luteal Phase:

1. Ruptured follicle becomes the corpus luteum.
2. Produces progesterone.
Female Reproductive System

Key Note

Oogenesis begins during embryonic development, and primary oocyte production is completed before birth. After puberty, each month the ovary produces one or more secondary oocytes from pre-existing primary oocytes. The number of viable primary oocytes declines with age, until ovarian cycles end at age 45–55.
Female Reproductive System

The Uterine Tubes (Fallopian Tubes)

- 5 inches long
- End in a funnel-shaped infundibulum
  - Opens into pelvic cavity
  - End are fingerlike projections= fimbriae
  - Ovum enters here after ovulation
- Ovum moves from infundibulum toward uterus -- takes 3-4 days
- Fertilization must occur during first 12–24 hours of its passage from infundibulum to uterus
The Uterus

- Protects and supports developing embryo
- Pear-shaped; 3in x 2in
- Anchored by several ligaments
- Regions
  1. Body
  2. Cervix inferior portion projects into vagina
  3. Uterine cavity
The Uterus (cont’d)

- Wall components
  1. Endometrium
     - Lining of cavity
  2. Myometrium
     - Smooth muscle layer
  3. Perimetrium
     - Serous covering
Female Reproductive System

The Uterus

- Ovarian artery and vein
- Ampulla
- Isthmus
- Perimetrium
- Fundus of uterus
- Uterine tube
- Body of uterus
- Ovary
- Broad ligament (mesentery)
- Myometrium
- Uterine artery and vein
- Infundibulum
- Fimbriae
- Internal os (internal orifice)
- Cervical os (external orifice)
- Cervical canal
- Vagina
- Round ligament of uterus
- Ovarian ligament
- Endometrium

Figure 19-11
The Uterine Cycle

• Also called, *menstrual cycle*

• Typically, 28 days long

1. Begins with

• Onset of *menses*

• Loss of the *functional zone* of endometrium

• Lasts one to seven days
The Uterine Cycle (cont’ d)

2. Proliferative phase follows menses
   • Repair, growth of functional zone of endometrium

3. Secretory phase follows
   • Endometrial glands become active
   • Uterus prepared for embryo
   • Menarche—First menses
   • Menopause—Cycles stop
The Vagina

- Muscular tube between uterus and external genitalia
- Highly elastic, distensible
- Partially blocked by **hymen**
  - Thin fold of epithelium
Female Reproductive System

Functions of the Vagina

1. Convey menstrual fluid
2. Receive penis during intercourse
3. Hold semen after ejaculation
4. Passageway for fetus during birth
The Mammary Glands

- Located within the breast
- Specialized organs of the integumentary system
- Produce milk to nourish the infant
- Lactation—The processes of milk synthesis and secretion by cells of the mammary glands
- Stimulated by hormones
Female Reproductive System

Mammary Gland of the Left Breast

- Pectoralis major muscle
- Pectoral fat pad
- Suspensory ligaments
- Lobes of the mammary gland
- Lactiferous duct
- Areola
- Nipple
- Lactiferous sinus

Figure 19-13
Hormones and the Reproductive Cycle

- Coordinate ovarian and uterine cycles
- *The ovarian follicle produces* estrogen
  1. Affects CNS, specifically hypothalamus to increase sex drive
  2. Stimulate bone and muscle growth
  3. Female secondary sex characteristics (body hair, fat deposits)
  4. Maintains accessory sex organs
  5. Initiates repair of endometrium
Female Reproductive System

- **Progesterone**— secreted by corpus luteum during the *luteal* phase of ovarian cycle
  1. Prepares uterus for pregnancy
  2. Stimulates growth of endometrium
  3. Stimulates metabolism and raises basal body temperature

- Ovulation triggered by mid-cycle *LH* surge
- Hypothalamic secretion of GnRH triggers pituitary to release FSH, LH
Female Reproductive System

Hormonal Regulation of the Female Reproductive Cycle

**Figure 19-14**

<table>
<thead>
<tr>
<th>Phases of the Ovarian Cycle</th>
<th>Follicular Phase</th>
<th>Luteal Phase</th>
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<tbody>
<tr>
<td>Gonadotropic hormone levels</td>
<td>FSH, LH</td>
<td></td>
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<tr>
<td>Follicular stages during the ovarian cycle</td>
<td>Follicle development, Ovulation, Corpus luteum formation, Mature corpus luteum, Corpus albicans</td>
<td></td>
</tr>
<tr>
<td>Ovarian hormone levels</td>
<td>Estrogens, Inhibin, Progesterone</td>
<td></td>
</tr>
<tr>
<td>Endometrial changes during the uterine cycle</td>
<td>Destruction of functional zone, Repair and regeneration of functional zone, Secretion of endometrial glands</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phases of the Uterine Cycle</th>
<th>MENSES</th>
<th>PROLIFERATIVE PHASE</th>
<th>SECRETORY PHASE</th>
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<tbody>
<tr>
<td>Basal body temperature (°C)</td>
<td>36.7</td>
<td>36.4</td>
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Female Reproductive System

Hormonal Regulation of the Female Reproductive Cycle

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</table>

(a) Days: 28/0  7  14  21  28/0

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Figure 19-14(a)
**Female Reproductive System**

**Hormonal Regulation of the Female Reproductive Cycle**

<table>
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<th>Luteal Phase</th>
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<tr>
<td>Follicular stages during the ovarian cycle (b)</td>
<td>Follicle development</td>
<td>Ovulation</td>
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<tr>
<td>DAYS</td>
<td>28/0</td>
<td>7</td>
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Figure 19-14(b)
**Female Reproductive System**

Hormonal Regulation of the Female Reproductive Cycle

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<td>Estrogens</td>
<td>Inhibin</td>
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Female Reproductive System

Hormonal Regulation of the Female Reproductive Cycle

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<td>7</td>
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Figure 19-14(d)
Female Reproductive System

Hormonal Regulation of the Female Reproductive Cycle

<table>
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Figure 19-14(e)
Key Note

Cyclic changes in FSH and LH levels are responsible for the maintenance of the ovarian cycle; the hormones produced by the ovaries in turn regulate the uterine cycle.
Male Sexual Function

• Arousal
  • Erotic thoughts, sensations lead to parasympathetic activity

• Erection
  • Sympathetic activity increases blood flow into erectile tissues of penis
Physiology of Sexual Intercourse

Male Sexual Function (cont’d)

• Coitus
  • Sexual intercourse increases sensation
• Emission
• Ejaculation
• Orgasm
  • Associated with strong contractions
Female Sexual Function

- Phases of sexual arousal resemble the male’s
- Parasympathetic activity during arousal
  - Clitoral erection
- Muscular contraction associated with orgasm
Menopause

- Time when menstruation and ovulation cease
- Normally occurs about age 50
- Production of sex steroids drops
  - Estrogen, progesterone
- Production of regulatory hormones rise
  - GnRH, FSH, LH
  - Negative feedback effect
The Male Climacteric

- Onset at about age 50–60
- Hormone levels change
  - Testosterone levels drop
  - FSH, LH levels rise
  - Negative feedback effect
- Sperm quantity and quality decline
The Reproductive System in Perspective

FIGURE 19-17
Functional Relationships Between the Reproductive System and Other Systems
The Integumentary System

- Covers external genitalia; provides sensations that stimulate sexual behaviors; mammary gland secretions provide nourishment for newborn
- Reproductive hormones affect distribution of body hair and subcutaneous fat deposits
The Skeletal System

- Pelvis protects reproductive organs of females, portion of ductus deferens and accessory glands in males
- Sex hormones stimulate growth and maintenance of bones; sex hormones at puberty accelerate growth and closure of epiphyseal cartilages
The Muscular System

- Contractions of skeletal muscles eject semen from male reproductive tract; muscle contractions during sexual act produce pleasurable sensations in both sexes

- Reproductive hormones, especially testosterone, accelerate skeletal muscle growth
The Nervous System

- Controls sexual behaviors and sexual function
- Sex hormones affect CNS development and sexual behaviors
The Endocrine System

- Hypothalamic regulatory hormones and pituitary hormones regulate sexual development and function; oxytocin stimulates smooth muscle contractions in uterus and mammary glands.
- Steroid sex hormones and inhibin inhibit secretory activities of hypothalamus and pituitary gland.
The Cardiovascular System

- Distributes reproductive hormones; provides nutrients, oxygen, and waste removal for fetus; local blood pressure changes responsible for physical changes during sexual arousal
- Estrogens may help maintain healthy vessels and slow development of atherosclerosis
The Lymphatic System

- Provides IgA for secretions by epithelial glands; assists in repairs and defense against infection
- Lysosomes and bactericidal chemicals in secretions provide nonspecific defense against reproductive tract infections
The Respiratory System

- Provides oxygen and removes carbon dioxide generated by tissues of reproductive system
- Changes in respiratory rate and depth occur during sexual arousal, under control of the nervous system
The Digestive System

- Provides additional nutrients required to support gamete production and (in pregnant women) embryonic and fetal development.
The Urinary System

- Urethra in males carries semen to exterior; kidneys remove wastes generated by reproductive tissues and (in pregnant women) by a growing embryo and fetus
- Accessory organ secretions may have antibacterial action that helps prevent urethral infections in males