

The Reproductive Systems

Sexual Reproduction

- Offspring produced by the joining (fertilization) of gametes
- Requires halving of chromosomes (46→23) through meiosis
 - Diploid →haploid
 - Separation of homologous chromosomes
 - Autosomes vs. sex chromosomes
 - Variability provided by fertilization, independent assortment of homologs, crossing-over (genetic recombination)

Possible Fertilization (graphic)

Meiosis I (graphic)

Meiosis II (graphic)

Reproductive Structures

- Gonads - gamete production
- Ducts - storage, maturation and transport of gametes
- Accessory sex glands - secretions that maintain gametes or aid in copulation
- Supporting structures - structures important in copulation or fetal development

Testicular Structure

- Contained in scrotum divided in two (septum) by fascia and dartos muscle (smooth)
- Tunica vaginalis - derived from peritoneum during descent through inguinal canal
- Tunica albuginea - protrudes anteriorly dividing testes in lobular arrangement
- Lobules contain seminiferous tubules - wall lined with spermatogenic cells (any stage) and sustentacular (Sertoli) cells
- Lobules also contain interstitial endocrinocytes (Leydig cells) - secrete testosterone

Scrotal Structures (graphic)

Ultrastructure of Testis (graphic)

Spermatogenic Cells

- Spermatogonia arranged at basement membrane of tubule, mitotically divide to form more spermatogonia ($2n$, stem cell source of endless supply)
- Some lose contact with basement membrane and differentiate to primary spermatocytes ($2n$)
- Continuing “maturity” with distance from basement membrane
- Secondary spermatocyte - result of first meiotic division (n but with chromatid duplicates)
- Spermatid - result of second meiotic division (n)
- Meiotic divisions don't complete cytokinesis - cytoplasmic bridges between cells

- Sperm or spermatozoa - result of spermiogenesis
 - Formation of acrosome and flagellum

Wall of Seminiferous Tubule (graphic)

Seminiferous Tubule (graphic)

SEM of Seminiferous Tubule (graphic)

Spermatogenesis (graphic)

Spermatozoa

- 300 million produced per day
- Head - DNA and acrosome (hyaluronidase and proteinases)
- Midpiece - mitochondria for ATP production
- Tail - flagellum

Sperm Structures (graphic)

Sustentacular Cells

- Large cells that reach from basement membrane to tubular lumen
- Tight junctions between adjacent cells causing blood-testis barrier
 - Important since sperm have foreign surface antigens which could cause immune response
- Variety of functions - control and protect spermatogenic cells, nourish developing sperm, phagocytize excess cytoplasm of developing sperm, influence effects of testosterone and FSH, produce fluid for sperm transport, secrete inhibin which regulates sperm production through negative feedback to FSH secretion

Hormonal Control

- GnRH produced by hypothalamus - increased at puberty
- Stimulates anterior pituitary gonadotrophic production of LH and FSH
- LH stimulates interstitial endocrinocyte (Leydig cell) production of testosterone
 - Lipid soluble - derived from cholesterol
 - Some target cells (e.g. prostate) convert it to dihydrotestosterone (DHT) - more potent form
 - Both alter gene action
- FSH stimulates spermatogenesis in concert with testosterone
 - Stimulates sustentacular cells to secrete androgen-binding protein (ABP) which hold testosterone in midst of spermatogenic cells (aiding in the completion of spermatogenesis)
- Blood testosterone levels control GnRH
- Inhibin from sustentacular cells control FSH

Hormonal Control (graphic)

Control of Testosterone Production (graphic)

Hormonal Effects

- Fetal development
 - Testosterone - internal structures and testicular descent

- DHT - external genitals
- Sexual characteristics at puberty
 - Enlargement of genitals, skeletal and muscle growth, body hair, increased sebaceous secretion, enlargement of larynx
- Sexual function - spermatogenesis and sexual behavior
- Metabolic function - protein anabolism (synthesis)

Male Ducts

- Seminiferous tubules → straight tubules → rete testis → efferent ducts → ductus epididymis → ductus deferens → ejaculatory duct → urethra
- Ductus epididymis - site of maturation (increased motility), storage (≈month), reabsorption of aging sperm, and peristaltic push into ductus deferens
- Ductus deferens (terminal expansion - ampulla) - storage (several months) and peristaltic push (three smooth muscle layers)
 - Spermatic cord passes through inguinal canal - hernia
 - Vasectomy
- Ejaculatory duct - combination of sperm and fluids from seminal vesicle, eject sperm into urethra
- Prostatic, membranous, and spongy urethra
- Ejaculation - sympathetic reflex - involves peristaltic contraction from ampulla through spongy urethra

Ultrastructure of Testis (graphic)

Male Accessory Structures (graphic)

Male Accessory Sex Glands

- Seminal vesicle - alkaline fluid with fructose (for ATP), prostaglandins (motility) and clotting proteins (unknown)
 - 60% of semen
- Prostate gland - milky, acidic with citrate (for ATP), acid phosphatase (unknown) and proteolytic enzymes including prostate-specific antigen (PSA) (liquefy clotted sperm)
 - 25% of semen
 - Enlarges after age 45
 - Prostate cancer
- Bulbourethral (Cowper's) gland - alkaline secretion during arousal and lubricating mucus

Semen Analysis

- Fertility evaluation
- Volume - 2.5-5 ml
- Count - 20 million/ml (typically between 50-150)
- Motility - 60%
- Morphology - <35% abnormality

- pH - 7.2 to 7.7
- Fructose - presence

Male Supporting Structures

- Scrotum
 - Testicular sac composed of loose skin, superficial fascia and dartos muscle (smooth), divided in two by septum
 - Cremaster muscle (skeletal) - continuation of internal oblique, passing through spermatic cord
 - Contraction of muscles important to regulation of scrotal temperature (3°C below body temp)
- Penis
 - Erectile tissue - corpora cavernosa, corpus spongiosum with tunica albuginea
 - Erection is a parasympathetic reflex causing vasodilation of arterioles
 - Erectile dysfunction - variety of causes, psychological, pathological, drug-related
 - Viagra enhances NO effect of vasodilation
 - Glans penis, prepuce (foreskin)
 - Bulb and crura of penis - points of muscular attachment which aid ejaculation

Scrotal Structures (graphic)

Erectile Tissue (graphic)

Penile Structures (graphic)

Ovarian Structure

- Ovaries held in place by ligaments to uterus and pelvic cavity wall
 - Broad ligament, ovarian ligament, mesovarium
- Germinal epithelium - surrounds ovary & continuous with layers of broad ligament and mesovarium
- Tunica albuginea - dense, irregular tissue capsule
- Ovarian cortex - dense connective tissue with ovarian follicles
- Ovarian medulla – loose connective tissue with blood, lymph and nerve supply
- Ovarian follicles - in varying stages
- Corpus luteum - degenerating follicle

Female Reproductive Structures (graphic)

Ovary (graphic)

Oogenesis

- Primordial germ cells migrate from endoderm and differentiate →oogonia (2n) during development
 - Many degenerate - atresia
- Primary oocytes (in prophase of meiosis I)
 - Surrounded by layer of follicular cells inclusively called primordial follicle

- 200K to 2M of oogonia and primary oocytes in each ovary at birth (40K at puberty, only 400 ultimately mature)
- Primary follicles – addition of layers of granulosa cells with separating zona pellucida (glycoprotein) layer
 - Production begins during childhood (pre-puberty)
 - Outer granulosa cells against basement membrane forming theca folliculi
 - Theca folliculi further develops into theca interna (vacularized layer of secretory cells) and externa (connective tissue)
- Secondary follicles - granulosa cells secrete follicular fluid forming antrum
 - These present at puberty
 - Other oocytes degenerate - atresia
- Secondary oocyte (n but with chromatid duplicates) - result of completion of meiosis I primarily due to monthly changes in FSH, second cell is smaller (first polar body), Graafian (mature) follicle containing secondary oocyte - result of advance to metaphase of meiosis II
- At ovulation, secondary oocyte released (with 1st polar body), if fertilized, completes meiosis II (n) and another polar bodies formed
- Sperm and ovum nuclei combine to form zygote ($2n$)

Ovary (graphic)

Primordial Follicles (Newborn) (graphic)

Primary Follicle (graphic)

Secondary Follicle (graphic)

Oogenesis (graphic)

Overview of Oocyte/Follicle Development (graphic)

Uterine Tubes

- Or oviducts or Fallopian tubes
- Infundibulum with fimbriae on perimeter
- Carry secondary oocytes or fertilized ovum (frequent site of fertilization up to 24 hrs after ovulation) to uterus
- 7 days to reach uterus
- Three layers
 - Mucosa - ciliated columnar epithelium and secretory cells for maintaining ovum
 - Muscularis - peristaltic smooth muscle contraction
 - Serosa
- Tubal ligation

Female Reproductive Structures (graphic)

Uterus

- Site of fertilized egg implantation and fetal development, source of menstrual flow
- Fundus, body, cervix; antiflexion

- Held in place by ligaments to pelvic cavity wall and sacrum
- Three layers
 - Endometrium - surface is ciliated columnar epithelium and secretory cells with areolar connective tissue below
 - Two layers - stratum functionalis (functional) with spiral arterioles (periodic removal) and stratum basalis (basal)
 - Myometrium - three layers of smooth muscle, thickest at fundus
 - Serosa or perimetrium
 - Hysterectomy – removal of uterus and possibly other related structures
- Cervical mucus - typically viscous, plugging cervix
- Primarily water, proteins, lipids, enzymes, salts
- Changes character during ovulation (more liquid and alkaline), otherwise it's a cervical plug
- Functions include: additional energy source for sperm, protection from vaginal environment & phagocytes, possible capacitation of sperm

Sagittal View of Female (graphic)

Sagittal Section of Female (graphic)

Uterine Structures (graphic)

Uterine Wall (graphic)

Vagina

- Site of sexual intercourse, passage of baby during birth and menstrual flow
- Fornix - site of cervical penetration
- Vaginal orifice with hymen
- Three layers
 - Mucosa - nonkeratinized stratified squamous epithelium and areolar connective tissue
 - Substantial glycogen stored in cells, when catabolized, produce organic acids contributing to low pH
 - Muscularis - two layers of smooth muscle
 - Adventitia - areolar connective tissue for attachment

Pap Smear

- Test for normal squamous cells in and around cervix
- Abnormal cells suggest possible cancer
- Colposcopy - examination of vaginal tissue using specialized magnifying scope
 - Follow up exam if secondary Pap test is positive

External Genitals

- Mons pubis
- Labia majora - both sebaceous and apocrine sudoriferous glands, homologous to scrotum
- Labia minora - many sebaceous glands, homologous to spongy urethra

- Clitoris - erectile tissue, homologous to glans penis
- Paraurethral glands - either side of urethral orifice, secrete mucus, homologous to prostate gland
- Greater vestibular (Bartholin's) glands - either side of vaginal orifice, secrete mucus, homologous to bulbourethral gland

Female External Structures (graphic)

Mammary Glands

- Modified sudoriferous (sweat) glands
- Milk production
 - Alveoli of lobules - site of milk production
 - Alveoli surrounded by myoepithelial cells which push milk out
 - Milk flows to secondary tubules → mammary ducts → lactiferous sinus (site of storage) → lactiferous ducts in nipple
 - Under influence of prolactin (secondarily progesterone and estrogens)
 - Milk ejection under influence of oxytocin - suckling stimulus

Mammary Gland (graphic)

Female Reproductive Cycle

- Includes ovarian cycle and uterine (menstrual cycle) dependent on hormonal/tissue interactions
- Hormone types (Fig. 28.25)
 - Hormonal levels frequently used to check for abnormal function
- Four primary phases (Fig. 28.26) - Menstruation, preovulatory (follicular includes menses or proliferative) phase, ovulation, postovulatory (luteal or secretory) phase

Reproductive Hormones (graphic)

Reproductive Cycle (graphic)

Menstrual Phase

- ≈20 secondary follicles begin to enlarge (filling of antrum with follicular fluid)
- Menstrual flow (removal of stratum functionalis) for about 5 days due to constriction of uterine arterioles (declining progesterone causes release of prostaglandins)

Preovulatory Phase

- Primary phase contributing to length variation in cycle
- Secretion of inhibin (& in part, estrogen) by developing follicles reduces FSH
- Less dominant follicles stop growing and deteriorate
- Dominant follicle(s) enlarges further (Graafian) and produces estrogen in response to increasing LH
- Estrogens foster endometrial growth

Hormone Cycling (graphic)

Ovulation

- High estrogen level causes positive feedback release of LH & GnRH (in absence of progesterone)
- Both FSH and LH increase
- High LH causes rupturing of Graafian follicle, releasing secondary oocyte

Initiation of Ovulation (graphic)

Postovulatory Phase

- LH stimulates formation of corpus luteum which secretes progesterone, estrogen, relaxin and inhibin
 - Progesterone and estrogen support endometrial growth and fluid secretion (glycogen-rich)
- If no fertilization, corpus luteum lasts about 14 days, and then degenerates
 - As luteal hormones decline, negative feedback on GnRH, FSH and LH declines
- If fertilization, growing embryo starts producing human chorionic gonadotropin (hCG)
 - Causes corpus luteum to continue secreting and maintenance of endometrium

Summary of Reproductive Cycle (graphic)

Birth Control

- Physical barrier
 - Condoms provide best HIV protection
 - Diaphragm
- Chemical including hormonal and spermicidal
 - Oral, Norplant, Depo-Provera, “Morning after pill”
 - Spermicides
- IUDs
- Rhythm
- RU 486 (mifepristone) – blocks progesterone sites.

Beginning and End

- Of reproductive cycle
- Puberty
 - Increased LH and FSH secretion along with respective testosterone or estrogens
 - Starts as sleep related increases
 - In females, both estrogens and progesterone initiate menarche by maturation of tubes, uterus and vagina
- Menopause
 - Declining responsiveness of anterior pituitary to GnRH and ovaries to FSH & LH