Urinary System

Chapter 24

Module 24.1: Overview of the Urinary System

OVERVIEW OF THE URINARY SYSTEM STRUCTURES

- **Urinary system** (organs of excretion) – composed of a pair of kidneys and urinary tract
    - _____ filter blood to remove metabolic waste products; modify resulting fluid for following purposes:
        - Fluid and electrolyte homeostasis
        - Acid-base and blood pressure homeostasis

    - **Urinary tract** – composed of a pair of **ureters**, urinary **bladder**, and a single **urethra**
        - Urine exits kidneys through_____found on posterior body wall
        - Each ureter empties into **urinary bladder** on floor of pelvic cavity where urine is stored
        - Urine exits from urinary bladder through_____; allows urine to exit body

OVERVIEW OF KIDNEY FUNCTION

- Kidneys are site where urinary system regulates homeostatic processes:
    - Filter blood to remove metabolic wastes
    - Regulate fluid and electrolyte balance
    -
    - Influence blood pressure
    - Releasing hormone **erythropoietin (EPO)**

-

-

- Kidneys look like beans in both shape and color
- Both kidneys are found <u>outside</u> and <u>posterior</u> to *peritoneal membrane*

  (_____)
- Right kidney is found in a slightly <u>inferior</u> position due to liver

- Left kidney is positioned <u>between</u> T_{12}–L_3 using vertebral column as reference
- 11th and 12th ribs provide some protection for <u>both</u> kidneys
- _____ – component of *endocrine system*; found on superior pole of each kidney

Module 24.2: Anatomy of the Kidneys

EXTERNAL ANATOMY OF THE KIDNEYS

- Three external layers of CT from deep to superficial:
  1. _____ – thin layer of dense irregular connective tissue; covers exterior of each kidney
  2. _____ – protects from physical trauma
  3. _____ – dense irregular CT; anchors each kidney to peritoneum and musculature of posterior abdominal wall
- **Hilum** – opening on medial surface of kidney where renal artery, vein, nerves, and ureters enter and exit

INTERNAL ANATOMY OF THE KIDNEYS

- Renal cortex and the renal medulla make up *urine-forming* portion of kidney
    - _____ 90–95% of all kidney's blood vessels are found in renal cortex
    - **Renal columns** – *extensions of renal cortex*; pass through renal medulla toward renal cortex
- Over one million **nephrons** are found within cortex and medulla of each kidney
    - **Renal corpuscle** found **in renal cortex**
    - **Renal tubule** found mostly in cortex with some tubules dipping into medulla
- Cone-shaped _____ are found within **renal medulla** separated by renal columns on either side
- Each renal pyramid tapers into a slender papilla

→

→

→

→

- Smooth muscle tissue contraction within walls of the calyces and renal pelvis propel urine towards ureter

BLOOD SUPPLY OF THE KIDNEYS

- Left and right **renal arteries** are branches of **abdominal aorta**

1- renal artery →

2- segmental artery →

3- interlobar artery →

4- _____ →

5- interlobular (**cortical radiate artery**)

- Kidney contains unusual capillary bed system where arterioles both feed and drain capillaries; normally function of a venule

6- afferent arteriole →

7- _____ →

8- efferent arteriole →

9- _____ capillaries

- Venous blood exits kidney *parallel to arterial pathway*

10- interlobular veins →

11- arcuate veins →

12- interlobar vein →

13- _____

- **Renal vein** exits kidney from hilum to drain into inferior vena cava

NEPHRON AND THE COLLECTING SYSTEM

- **Nephron** – renal corpuscle and renal tubule
  - **Renal corpuscle** –filters blood

- **1._____** – group of looping fenestrated capillaries
  - **2. Glomerular capsule** (**Bowman's capsule**) – consists of outer parietal & inner visceral layer
    - _____ **space** – hollow region between parietal and visceral layers

- Filtrate from Bowman's capsule enters **renal tubule**:

  _____ **(pct)**

  -

  _____ **(descending limb, ascending limb)**

  -

  _____ **(dct)**

  -

- **Juxtaglomerular apparatus** (**JGA**)

  - composed of both **macula densa** and **juxtaglomerular** (**JG**) **cells**;

  - **Macula densa** is a group of cells in contact with modified smooth muscle cells (**juxtaglomerular** (**JG**) **cells**)

- JGA regulates *blood pressure (**BP**)* and *glomerular filtration rate* (***GFR***)

  - _____
  - _____

- **Collecting system** – both medullary collecting duct (**cd**) and papillary duct that *further modify* filtrate before it exits kidney

  - **cortical cd → medullary cd →** _____

- Once filtrate enters papillary duct it is known as urine, <u>not</u> filtrate
- Urine exits papillary duct at papilla of renal pyramid into a _____

TYPES OF NEPHRONS

- _____ **nephrons** make up about 80% of nephrons in kidneys

  - Renal corpuscles are found in outer renal cortex; have short nephron loops that barely enter renal medulla
- _____ **nephrons** – much less common than cortical nephrons
  - Renal corpuscles are found near boundary between renal cortex and medulla; have long nephron loops that travel deep within renal medulla

- **Cortical nephrons** make up about 80% of nephrons in kidneys
  - Renal corpuscles are found in outer renal cortex; have short nephron loops that barely enter renal medulla
- **Juxtamedullary nephrons** – much less common than cortical nephrons
  - Renal corpuscles are found near boundary between renal cortex and medulla; have long nephron loops that travel deep within renal medulla

Nephrolithiasis

- Formation of **renal calculi** (_____); crystalline structures composed most commonly of *calcium oxalate salts*
- Form when concentrations of ions (also sodium ions, hydrogen ions, and uric acid) are present in filtrate in higher than normal amounts; known as **supersaturation**

Module 24.3: Overview of Renal Physiology

GLOMERULAR FILTRATION

- Selectively based on size so_____and_____are not filtered and remain in the circulating blood

- Smaller substances exit blood to enter capsular space as filtrate

  Filtration =

TUBULAR REABSORPTION

- Reclaiming or reabsorbing substances such as water, glucose, amino acids, and electrolytes from tubular fluid to return them into circulating blood

  Reabsorption =

TUBULAR SECRETION

- Substances are added into filtrate from peritubular capillaries

  - Helps maintain electrolyte and acid-base homeostasis; removes toxins from blood that did not enter tubular fluid by filtration

    Secretion =

Module 24.4: Renal Physiology I: Glomerular Filtration

- Fenestrated glomerular capillary
  - Fenestrations <u>are large pores</u>
  - Water and small dissolved solutes pass through filtration membrane easily
  - Nitrogenous wastes – group of small substances that are readily filtered; include:
    - _____ and ammonium ions (NH_4^+) from protein metabolism
    - Creatinine
    - _____ – product of nucleic acid metabolism

Filtration Membrane:

1. Fenestrated glomerular_____cells
2. Basal lamina
3. Podocytes

GLOMERULAR FILTRATION RATE

Amount of filtrate formed by both kidneys in one minute is known as **glomerular filtration rate** (**GFR**); 125 ml/min (_____)

- **Net filtration pressure** at glomerulus is determined by three driving forces:

  1. **Glomerular hydrostatic pressure ( )** – blood pressure; higher than average capillary bed hydrostatic pressure

  2. **Glomerular colloid osmotic pressure ( )** – created mostly by albumin; pulls water back into glomerular capillaries

  3. **Capsular hydrostatic pressure** ( ) – generated as capsular space rapidly fills with new filtrate (10 mm Hg) as fluid can only move so quickly into renal tubule which opposes filtration

- **Net filtration pressure** (**NFP**) is combination of these three forces:

  NFP = **GHP** – (**GCOP** + **CHP**)

- NFP favors filtration as GHP is greater than sum of forces that oppose filtration (GCOP + CHP)

Glomerulonephritis

- Common condition that involves damage to and destruction of glomeruli; **inflammation** of glomerular capillaries and basement membrane results.

- Inflammation <u>increases</u> *blood flow* and *capillary permeability*; increases GHP; causes filtration membrane to become excessively leaky; leads to *loss of blood cells* and *proteins* to urine

FACTORS THAT AFFECT THE GLOMERULAR FILTRATION RATE

Autoregulation – internal kidney mechanisms that work to maintain GFR

- _____ **mechanism** – constriction of smooth muscle in blood vessel walls in response to increases in BP
- **Tubuloglomerular feedback** – uses **macula densa** of distal renal tubule to control pressure in glomerulus in response to NaCl concentration of filtrate
- Hormonal effects on GFR are part of a larger system that involves regulation of *systemic BP* and includes angiotensin-II and natriuretic peptides
    - **Renin-angiotensin-aldosterone system** (**RAAS**) – complex system that maintains systemic BP
    - **Atrial natriuretic peptide** (**ANP**) – hormone released by heart cells in **atria** in response to increasing fluid volume; lowers blood volume and BP to reduce workload of the heart
        - ANP increases *GFR* by dilating *afferent arterioles* and constricting *efferent arterioles*; increases glomerular hydrostatic pressure
- Neural regulation of GFR primarily involves_____of ANS

RENAL FAILURE

- If GFR_____, kidneys may be unable to carry out their vital functions; called **renal failure**
    - Renal failure may be a short-term condition known as **acute renal failure** or **acute kidney injury**; *resolves* with treatment

- Renal failure may become **chronic** after three or more months of decreased GFR; commonly seen with long-standing *diabetes mellitus* and *hypertension*

- _____ – condition that can develop when GFR is <u>less</u> than *50% of normal*; leads to buildup of *waste products*, *fluid*, *electrolytes*, as well as *acid-base imbalances*, all of which can lead to coma, seizures, and death if untreated

- _____ can be used to treat the signs and symptoms of uremia

The RAAS and Hypertension

- Three classes of drugs have been developed that act on RAAS to <u>reduce</u> *blood pressure*:

- **ACE inhibitors** – developed from snake venom; block ACE; therefore *inhibit conversion of angiotensin I to II*
  - **Angiotensin-receptor blockers** – block receptors on blood vessels and proximal tubule cells; *prevents* vasoconstriction and *reabsorption of water and sodium*
  - **Aldosterone antagonists** – block effects of aldosterone on distal tubule; decrease reabsorption of sodium and water; leads to *diuretic effect*

- Drugs may <u>decrease</u> GFR in patients with *pre-existing renal disease*; must be monitored

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Module 24.5: Renal Physiology II: Tubular Reabsorption and Secretion

PRINCIPLES OF TUBULAR REABSORPTION AND SECRETION

- In_____, substances pass from filtrate into interstitial fluid then into peritubular capillaries to re-enter blood

- In **tubular secretion**, substances move in *opposite direction*

- _____ – substances move from blood into interstitial fluid then into tubule with filtrate

  - Secretion is an **active process**

REABSORPTION AND SECRETION IN THE PROXIMAL TUBULE

- Reabsorption is the main function of _____
  - Large quantity of ions, sodium, potassium, chloride, sulfate, and phosphate; vital to electrolyte homeostasis
  - Almost 100% of nutrients including glucose, amino acids, water-soluble vitamins, and lactic acid

Glycosuria

- **Transport maximum** – especially important with substances such as **glucose**
- If too much glucose is present in filtrate, TM will be reached before all glucose is reabsorbed; excess will appear in urine (**glycosuria**)

- Commonly seen in **diabetes mellitus** – due to defects in production of or response to **insulin**, causes inability of cells to take up glucose; leads to high circulating blood glucose (**hyperglycemia**), high filtrate glucose content, and therefore glucose remaining in urine

Secretion in Proximal tubule

- Ammonium ions (NH_4^+), creatinine, and small amounts of urea are also secreted

- Drugs such as penicillin and morphine have significant renal secretion; must be taken often (typically 3–5 times per day), because amount lost through renal secretion must be replaced in order to maintain *relatively consistent blood levels*

REABSORPTION IN THE NEPHRON LOOP

- Once filtrate reaches nephron loop, 60–70% of water and electrolytes and most organic solutes have been reabsorbed (returned to blood)

- About 20% of water and 25% of sodium and chloride ions are reabsorbed from loop

REABSORPTION AND SECRETION – DISTAL TUBULE & COLLECTING SYSTEM

Facultative water reabsorption – water is reabsorbed based on body's needs

- _____ –from adrenal cortex; increases reabsorption of sodium ions from filtrate and secretion of potassium ions into filtrate
- _____ (ADH) – from hypothalamus and secreted by posterior pituitary; causes water reabsorption; reduces urine output
- **Atrial natriuretic peptide** (ANP) – stimulates urinary excretion of sodium ions while it also inhibits release of both aldosterone and ADH

Medullary collecting system – last chance for regulation of fluid, electrolyte, and acid-base balance before filtrate becomes urine

- Impermeable to water in absence of _____
- Permeable to urea; allows urea to be reabsorbed passively into interstitial fluid
- Cells of proximal tubule secrete hydrogen ions to maintain blood pH

Module 24.6: Renal Physiology III: Regulation of Urine Concentration and Volume

PRODUCTION OF DILUTE URINE

- Kidneys produce dilute urine when solute concentration of extracellular fluid is too low
  -
  - Distal tubule and collecting duct become impermeable to water
  -

COUNTERCURRENT MECHANISM & PRODUCTION OF CONCENTRATED URINE

- Kidneys effectively conserve water by producing very concentrated urine (reaching nearly 1200 mOsm) using two mechanisms:
  - Countercurrent mechanism creates and maintains osmotic gradient by exchanging materials in opposite directions between filtrate and interstitial fluids
  - **Countercurrent multiplier** proceeds in following steps
  - NaCl is actively transported _____ filtrate into interstitial fluid
  - Hypertonic fluid then pulls water out of filtrate in _____ into interstitial fluid

Module 24.8: Urine and Renal Clearance

- URINE COMPOSITION & URINALYSIS
  -
  -
  - Potassium
  - Chloride
  -
  - Phosphates
  - Sulfates
  - Metabolic wastes such as urea, creatinine, ammonia, and uric acid
  - Small amounts of bicarbonate, calcium, and magnesium may be present

- Urine **color**
  - _____; breakdown product of hemoglobin
  - Darker urine is more concentrated; has less water
  - Lighter urine is less concentrated; has more water
- Urine should be _____
- Mild odor; strong odor may be caused by diseases, infections, or by ingesting certain foods
- Normal pH (6.0); ranges from _____
- **Specific gravity** 1.001 (very dilute) to 1.035 (very concentrated)

- **Renal clearance**:
  - Measurement of rate at which kidneys remove a substance from blood
  - For a substance to provide an accurate measure of renal clearance and GFR, substance should be completely filtered and neither reabsorbed nor secreted
  - **Creatinine** –not totally accurate (5–50% in urine arrived via *secretion*, not filtration)
  - More accurate assessment of GFR can be obtained using **inulin**; neither secreted or absorbed; must be *injected*

Module 24.9: Urine Transport, Storage, and Elimination

ANATOMY OF THE URINARY TRACT

Urinary tract consists of two ureters, urinary bladder, and urethra

- **Ureter** is 25–30 cm long and empties into bladder

1. _____ – most superficial layer; made of fibrous connective tissue
2. _____ – middle layer; made of smooth muscle cells that contract rhythmically (peristalsis) to propel urine toward urinary bladder
3. _____– deepest layer; mucous membrane composed of transitional epithelium

- **Urinary bladder** – hollow, distensible organ found on pelvic cavity floor
  - _____ – *triangular region* on bladder floor; openings of two ureters are found at each posterior corner
  - Bladder wall:

    1. Adventitia – most superficial layer; made of areolar connective tissue

    2. Detrusor muscle – middle layer; squeeze bladder; (**internal urethral sphincter**) is found at opening of urethra

    3. _____ – innermost layer; made of transitional epithelium

  - _____– drains urine from urinary bladder to outside of body; walls are similar to ureters
    - A second **external urethral sphincter** is formed by **levator ani muscle** – *skeletal muscle* of pelvic floor; allows for voluntary control of urination
  - Male and female urethra differ structurally and functionally
    - *Female* – about four cm in length; opens at **external urethral orifice** between vagina and clitoris
    - *Male* – about 20 cm, consists of following three regions:

      1. _____ urethra
      2. _____ urethra
      3. _____ (penile) urethra

MICTURITION

- **Micturition** –_____; discharge of urine from urinary bladder to outside of body
- **Micturition reflex** – reflex arc mediated by **parasympathetic nervous system** when urine fills bladder and stretches walls:
  - **Stretch receptors** send a signal to sacral region of the spinal cord via sensory afferent fibers
  - _____ efferent fibers stimulate detrusor muscle to contract and internal urethral sphincter to relax; allows for micturition
- **Micturition center** – found in **pons** (CNS); given time and training makes micturition a *voluntary process*

Fluid, Electrolyte, and Acid-Base Homeostasis

Chapter 25

Module 25.1: Overview of Fluid, Electrolyte, and Acid-Base Balance

INTRODUCTION TO BODY FLUIDS

Body fluids – blood plasma, interstitial fluid, cytosol, CSF, lymph and exocrine secretions

- Mostly water

- Fluid balance –maintaining volume and concentration of body's intracellular (___) and extracellular fluid (_____)
- Water that is gained must equal water that is lost
    - (H_2O in = H_2O out)
- Multiple factors impact fluid balance including:
    - Amount ingested
    -
    -
    - Medications
    - Digestive activities

ELECTROLYTES

- **Electrolytes** – substances that dissociate into ions, or charged particles
    - Electrolytes obtained from diet equals those lost
    - Controlled mostly by _____

- Ion concentration is dependent not only on number of ions in a body fluid, but also on amount of water in body fluid
- Fluid balance is a critical factor that determines electrolyte balance
-

ACIDS, BASES, and pH

- An acid is a chemical that dissociates in water to release a _____
  - H^+ ion plays a role in: digestion of food, inactivation of microbes and pathogens, and intracellular digestion in lysosomes
- A_____or alkali, is a chemical that accepts a H+ or releases a hydroxide ion (_)
  - Bicarbonate and other bases are components of buffer systems

- **pH scale** – used to measure [H+] of a solution
  - An <u>increase</u> in hydrogen ion concentration results in a solution with a <u>lower</u> pH
  - Solutions with a <u>lower</u> hydrogen ion concentration have a <u>higher</u> pH

pH less than 7 are _____
pH greater than 7 are _____
pH of 7 are _____

Module 25.2: Fluid Homeostasis

FLUID COMPARTMENTS

- **Intracellular fluid** (**ICF**); accounts for about **60%** of body's fluids
- **Extracellular fluid** (**ECF**) composed of a variety of body fluids
  - _____ – about **8%** of total body water
  - _____– about **32%** of total body water

- Solute composition of ECF and ICF varies
  - _____, chloride, calcium, and bicarbonate ions are higher in ECF
  - _____, magnesium, sulfate, and monohydrogen phosphate ions higher in cytosol

WATER LOSSES AND GAINS

- **Factors that influence water loss** – majority of water lost daily is in urine via kidneys

1. **Obligatory water loss** – (500 ml) urine produced daily irrespective of fluid intake
   - Required to prevent toxic buildup of molecules and electrolyte imbalances
2. **Sensible water loss** – usually about 100 ml in feces (noticeable amount of water lost)
3. **Insensible water loss** – usually 600 ml from skin in form of sweat and evaporation

- 300 ml lost in expired humidified air (an unnoticed amount of daily water loss)

- Most people lose about _____ of water daily

Fluctuates with water intake, physical activity, and food intake

Water Gains:

1. Water ingested from foods ( )
2. Metabolic water ( )
3. Drinking liquid ( )

Water intake driven by **thirst mechanism:**

1. Osmoreceptors in hypothalamus

2. Decreased plasma volume that results in a BP drop detected

   by baroreceptors →

   Stimulates juxtaglomerular cells →

   renin-angiotensin-aldosterone system → angiotensin-II →

   _____

HORMONAL REGULATION OF FLUID BALANCE

- **ADH** (**antidiuretic hormone**) plays most important role in balancing water intake with water loss, or fluid balance
  - Produced in hypothalamus and released from posterior pituitary
  - _____ and _____ reabsorb water
  - Increased ADH leads to more water reabsorption that decreases urine volume
  - Decreased ADH leads to more water elimination that increases urine volume

IMBALANCES OF FLUID HOMEOSTASIS

- _____ – decreased volume and increased concentration of ECF
  - Common causes include: profuse sweating, diarrhea and/or vomiting, some endocrine conditions, and diuretic overuse
  - Water loss decreases plasma volume and increases solute concentration; increases osmotic pressure
- **Overhydration** (**hypotonic hydration**) – when ECF volume increases; decreases its osmotic pressure

- ADH secretion is abnormal or an extreme amount of water is consumed in a brief time period (_____)
- Electrolyte imbalances, especially sodium ion decreases (**hyponatremia**) result from diluted ECF

Module 25.3: Electrolyte Homeostasis

SODIUM

- Sodium ions are most abundant in ECF
- Regulation of sodium ion concentration:
  - Angiotensin-II and aldosterone are two main hormones that increase Na^+ retention
  - ANP decreases Na^+ and water reabsorption
  - **Hypernatremia** – elevated Na^+ concentration; greater than 145 mEq/l; commonly caused by *dehydration*
  - **Hyponatremia** – decreased Na^+ concentration; less than 135 mEq/l; commonly caused by *overhydration*

POTASSIUM

- **Potassium ions** are most abundant in ICF
- **Regulation of potassium ion concentration:**
  - Insulin, aldosterone, and epinephrine are hormones that stimulate uptake of K^+ by cells (**endocrine control**)
  - Excess K^+ is secreted into urine and excreted from body (_____)
- **Hyperkalemia** – high K^+ in plasma

  - Potentially fatal; resting membrane potential more positive (cells incapable of functioning)
- **Hypokalemia** – low K^+ in plasma
  - Commonly caused by **diuretics** that lead to excess K^+ loss in urine
  - RMP more negative (less responsive to stimuli)

Module 25.4: Acid-Base Homeostasis

HYDROGEN IONS AND BUFFERING SYSTEMS

- *Normal* H^+ level in body fluids equals a pH range of about **7.35–7.45**
- pH is maintained by:
  - Respiratory and urinary system using two types of **buffer systems**

    1. Chemical buffer systems

    2. Physiological buffer systems

Acid-Base Imbalances

- **Acidosis** - body fluid pH of less than 7.35,
  - More H^+ are added
  - Acidosis causes neurons to become less excitable; leads to signs and symptoms of nervous system depression
- **Alkalosis** - body fluid pH greater than 7.45
  - more base ions are added
  - Increases excitability of neurons causing them to fire APs inappropriately

Reproductive System

Chapter 26

26.1 Overview of the Reproductive System and Meiosis

Introduction to the Male and Female Reproductive Systems

Similarities between male and female reproductive organs:

- _____ secrete **sex hormones**, including testosterone and estrogen
- Gonads produce_____by meiosis; male gametes are called **sperm** and female gametes are called **ova**, or egg cells
- Both genders have additional organs **accessory reproductive organs**

Cell division can occur either by **mitosis** that produces identical daughter cells or **meiosis** that produces sex cells

- **Fertilization** – process by which a sperm and egg cell fuse to form a new cell called a **zygote**
  - _____ – cell that divides to produce all of cells in a new individual
  - Must contain correct number of chromosomes; half from ovum and half from sperm

Overview of Meiosis

- _____ – process during which a cell divides to form daughter cells with half number of chromosomes; ensures correct number in gametes and eventually zygote
  - All human somatic cells have a nucleus with 46 chromosomes (23 pairs)
  - Somatic cells are_____(**2n**) because they have full paired set of chromosomes

Comparing Mitosis and Meiosis

- Mitosis occurs because new cells are needed for tissue growth or repair; new cells must be genetically identical to original
- Meiosis produces sperm and ova for reproduction; cells need to have half chromosome number of original cell

26.2 Anatomy of the Male Reproductive System

Testes

Testes (**testicles**) – located outside abdominopelvic cavity in the **scrotum**

- Each testis is divided into _____; contain tightly coiled loops called **seminiferous tubules** where sperm is produced
- Testes perform two important functions: sperm production and secretion of _____

Seminiferous tubules contain two cell types:

1. _____ (sperm-forming cells) and
2. _____ cells; *support* sperm production

- **Interstitial cells** (Leydig cells) – found between seminiferous tubules
  -
- **Myoid cells**, muscle-like cells that surround seminiferous tubules, contract to push sperm and testicular fluid through tubules

Seminiferous tubules →

_____ →

Rete testis →

Efferent ductules →

_____

Duct System

- **Epididymis** – filled with ductules; site of sperm_____and _____
- **Ductus deferens** begins at end of epididymis
    - Travels with testicular arteries, veins, and nerves within a **spermatic cord** through the_____into pelvic cavity
    - Mucosa consists of PSCCE and smooth muscle, called **muscularis**
    - Ductus deferens can store sperm for months and reabsorb any sperm that has not been ejaculated
- _____ –receives sperm from ductus deferens at the **seminal vesicle**
    -
- _____ – transports both urine and semen

The Penis

- _____ **–** attaches to body wall
- _____ or **shaft** – contains erectile tissue
- _____ where external urethral orifice is located

Loose skin of penis forms a circular fold called **prepuce,** or **foreskin**; portion removed by **circumcision**

- **Internal penis** – includes three cylindrical **erectile bodies** (**corpora**)
    - Each erectile body is a *spongy network* of connective tissue and smooth muscle with vascular spaces
    - _____ – paired erectile bodies
    - _____ at base

Accessory Sex Glands

- _____ –found on posterior surface of urinary bladder meets with ductus deferens to form ejaculatory ducts
    - **Seminal fluid** –
        - **Fructose** – sugar that sperm utilize for ATP synthesis
        - **Prostaglandins** – stimulate smooth muscle contraction
        -
        - pH of seminal fluid is alkaline to *neutralize* acids
- _____ – inferior to urinary bladder; surrounds urethra and ejaculatory ducts
        - Made up of 20–30 tubular glands and smooth muscle
    - **Prostatic secretions** –
        - **Citrate** –sugar that sperm can utilize
        - **Prostate specific antigen** (**PSA**)– dissolve semen clot in female reproductive tract to allow sperm to proceed further into tract
        - **Antimicrobial chemicals** – inhibit some bacterial growth to decrease risk of infection in female reproductive system

Benign Prostatic Hyperplasia (BPH) and Prostate Cancer

- Enlargement of the prostate that is noncancerous but expands to point of compressing urethra, condition is called **benign prostatic hyperplasia**, or **BPH**
- _____; second most common cancer in U.S. men
- Screening for prostate cancer usually includes a digital rectal examination and assessment of blood **prostate-specific antigen** (_____) levels
-

- _____ **glands** (**Cowper's glands**) – paired glands found at base of penis on either side of membranous urethra
    - Secrete a thick, alkaline mucus-like fluid that helps neutralize
    - Also lubricate glans penis during intercourse
    -

Semen

Sperm –5% of semen volume

- Typical **ejaculate** is between 2.5 and 5 ml in volume; contains between 40–750 million sperm cells

Male Infertility

- **Infertility** – inability to produce a pregnancy after one year of unprotected intercourse
- Approximately 40 percent of all infertility cases result from male infertility; usually due to a low sperm count
    -
    - Low sperm count can result from any sort of damage to testis, such as physical trauma, exposure to radiation, or disease; could also be due to developmental defects
- During normal development, testes begin forming inside abdominopelvic cavity and then descend into scrotum
- If a testis does not descend into scrotum (disorder called **cryptorchidism**) sperm cells will not be produced
- In addition, inadequate secretion of GnRH, FSH, LH, or testosterone for any reason will also lower sperm count.

Support Structures: Scrotum and Spermatic Cord

-
    - Midline _____ divides scrotum into two compartments,
    - Scrotum wall contains a layer of smooth muscle called _____
- _____ – tube extending from scrotum; contains ductus deferens, blood and lymph vessels, and nerves; leads to pelvic cavity
    - **Inguinal canal** leads into abdominal cavity
    - _____ – smooth muscle that controls height of testes
    - Normal body temperature (37° C) is too warm for mass production of viable sperm cells; scrotum is generally 3° C cooler

26.3 Physiology of the Male Reproductive System

Spermatogenesis

- Begins at *puberty* and continues for duration of lifespan
- Occurs in seminiferous tubules

_____ (2n) - stem cells

-

- some differentiate into →

(1)_____(2n)

- meiosis I →

(2)_____(n)

- meiosis II →

(4)_____(n) → spermatozoa

Sustentacular cells (nurse cells, Sertoli cells)

- Provide nutrients for dividing cells and produce **inhibin**, which help regulate spermatogenesis
- Phagocytize damaged spermatogenic cells

Sperm

- Spermatids develop a head, midpiece, and tail as they mature into sperm cells
  - _____ – contains nucleus and acrosome
  - _____ – contains mitochondria
  - _____ – flagellum
- Sperm are still nonmotile as they migrate to epididymis where they will complete maturation process
  - Trip takes about 12 days to reach epididymis and mature where sperm cells will remain viable for months
  - Entire process takes 60–70 days to complete
  -

Hormonal Control

- **Gonadotropin-releasing hormone** (_____) – hypothalamus
- Anterior pituitary detects GnRH; stimulates secretion of **follicle-stimulating hormone** (_____) and **luteinizing hormone** (_____)
- FSH stimulates sustentacular cells to work and release_____hormone
-
- _____ – main hormone involved in regulation of spermatogenesis and male reproductive physiology

- Elevated testosterone and inhibin levels are sensed in hypothalamus and anterior pituitary causing negative feedback loop to close
- Inhibin decreases release of FSH; testosterone reduces GnRH secretion

Male Sexual Response

- Erection and ejaculation are basic phases of male sexual response (similar affects in females)
    - _____ –_____reflex triggers release of nitric oxide (NO) from blood vessels
    - Arterioles dilate in erectile tissue; allows for a large volume of blood to enter tissue
    - In non-aroused state penis is **flaccid** (relaxed) as blood vessels supplying penis are constricted
- _____ – time period during which feelings of pleasure are experienced; coincides with ejaculation
- _____ – process to expel semen from penis; under _____ nervous system control that occurs in two stages:
    - _____ – movement semen into urethra
    - _____ – occurs as semen pushes from urethra

Effects of Testosterone

Testosterone levels increase dramatically at puberty typically between 12 and 14 years of age in males

-
- Increased testosterone levels trigger spermatogenesis and appearance of **secondary sexual characteristics**
    - Growth of pubic, axillary, chest, and facial hair

-

- Skin thickens and sebaceous glands increase secretion

-

-

- Erythrocyte production increases as testosterone increases erythropoietin secretion
- Testosterone influences behavior; basis for male **libido**

Erectile Dysfunction

- Various psychological and physical factors may cause **erectile dysfunction** (**ED**)
  - Psychological influences include stress, depression, and anxiety;
  - Physical causes include cardiovascular disease and diabetes mellitus; obesity, tobacco, and alcohol use, and certain prescription medications
  - Older men have a greater risk because the amount of connective tissue in erectile tissue of penis increases with age, reducing blood flow to penis

26.4 Anatomy of the Female Reproductive System

Ovaries

-

- Secrete *hormones*: estradiol, estrone, and estriol, as well as progesterone, inhibin, and relaxin
- _____ – *superficial* region where **oogenesis** (production of gametes) occurs within saclike **follicles**; develop and mature along with gametes
- _____ – *inner* region where blood vessels, lymphatic vessels, and nerves are found

- Ovaries are held in place by three ligaments

  1. _____ ligament – connects ovary to bony pelvis

  2. _____ ligament – connects ovary to uterus

  3. _____ ligament – connects ovary to pelvic wall

Uterine tubes (**fallopian tubes**, or **oviducts**)

-
- **Isthmus** – found at proximal end of tube, connects to uterus
- **Ampulla** – expansion at distal end that connects tube to infundibulum
- **Infundibulum** – funnel-shaped opening at distal end of uterine tube (**Fimbriae** – finger-like projections)
- _____ – an oocyte is expelled from ovary; fimbriae sweep ovary surface to catch oocyte and direct it into uterine tube
  - Peristaltic contraction and ciliated cells work to move the oocyte toward uterus
  -

Uterus

Uterus (**womb**) –hollow organ located in pelvis anterior to rectum and posterior to urinary bladder

- _____ – main region
- _____ – rounded region superior to entrance to uterine tubes
- _____ – narrow neck
- Uterine wall is composed of three layers:

  1. _____ – Outermost serous layer

2. _____ – middle layer of smooth muscle

3. _____ – innermost layer that lines uterine cavity; composed of simple columnar epithelium

Vagina

Organ of copulation; receives penis and semen during sexual intercourse; passageway for giving birth and for menstrual flow

-
- Parallel to urethra; lies between urinary bladder and rectum
- Vaginal wall is lined with transverse ridges called _____
- Mucosa is composed of stratified squamous epithelium
    - Epithelial cells secrete glycogen into vaginal lumen
    - Metabolized by bacteria
    -
- _____ – vascular partition of mucosa near distal vaginal orifice; commonly ruptured during first sexual intercourse

Female External Genitalia

- _____ – external reproductive structures
- _____ –rounded region overlying pubic symphysis
- _____ – pair of elongated protective skin folds
- **Labia minora** – pair of thinner skin folds found enclosed within labia majora
    - _____ – recess enclosed within labia minor contains **Vestibular glands** (**Bartholin's glands)**
- _____ – anterior to vestibule; small protrusion composed of erectile tissue

Mammary Glands

-
- Each mammary gland is found within hypodermis and enclosed within a rounded, skin-covered breast
- **Areola** – surrounds a **nipple** through which milk exits
- Each mammary gland is composed of 15–25 **lobes**
  - Each lobe is subdivided into smaller **lobules**; contain _____ which produce milk when a woman is lactating
  - _____ that surround alveoli helps propel milk toward nipple
  - Milk passes from alveoli → lactiferous ducts → lactiferous sinus → nipple

Breast Cancer

- **Breast cancer** – second most common type of cancer in women
- **Risk factors** for breast cancer include maternal relatives with breast cancer, longer reproductive span (early first menstrual cycle coupled with menstruation continuing until a later age), obesity, no pregnancies or first pregnancy at or after age of 35, and presence of breast cancer genes; two genes that increase susceptibility to breast cancer have been identified: *BRCA1* and *BRCA2*

26.5 Physiology of the Female Reproductive System

Oogenesis

- Begins before female infant is born, then is suspended until puberty
- Once reactivated at_____continues until it ceases operation at _____, somewhere between 45 and 55 years of age
- Occurs about once per month as a part of **ovarian cycle**

_____ **(2n)** - stem cells in female complete mitosis

3-7th month of fetal development

_____ **(2n)** - about 2 million present at birth

- undergo_____(degeneration) → 400,000 at puberty

_____ **(n)** - ovulated mid-cycle each month, alternating ovaries (polar body formed)

_____ **(n)** - completes meiosis II after fertilization

Spermatogenesis versus Oogenesis

- Spermatogenesis produces millions of sperm every day (in case they are needed), whereas oogenesis produces one viable secondary oocyte approximately once a month

Hormonal Control of Female Reproduction

- _____ – includes *monthly* series of events associated with maturation of an oocyte and its follicle in an ovary
- **Follicular phase** (**stages 1–4**): During this phase follicles grow and develop:

  1. _____ – single layer of squamous **follicular cells** surrounds primary oocyte

  2. _____ **follicle** – follicular cells become grow around primary oocyte

  3. _____ **follicle**: increases volume and size of follicle, small pockets of fluid form

  4. Vesicular (_____) **follicle**: large cavity called **antrum** forms, primary oocyte, completes meiosis I to form a secondary oocyte and first polar body

- **Ovulation phase** (**stage 5**)

  -

- **Luteal phase** (**stages 6–7**):

  6._____ is formed by the remaining follicle; secretes progesterone and some estrogen

  7. _____ – scar tissue that remains after corpus luteum is degraded

- Ovarian cycle averages about 28 days overall, with each stage accounting for following amount of time:
  - Follicular phase extends from day one to day 14
  - Luteal phase extends from day 14 to day 28
- Hormones of 28-day cycle:
  - Hypothalamus secretes _____ (**gonadotropin-releasing hormone**)
  - Anterior pituitary releases LH and FSH in response to GnRH
  - FSH stimulates follicle cells to secrete estrogens and secretes inhibin
  - Estrogens typically stimulate dominant follicle to continue developing into a vesicular follicle
  -
  - Corpus luteum produces progesterone and estrogens
  - Increased levels of estrogen and inhibin exert negative feedback control on hypothalamus and pituitary
  - Estrogen inhibits GnRH and LH secretion
  -
- Estrogen and progesterone stimulate development of **female sex characteristics**:
  - Maturation of sex organs and development of external genitalia
  -

- Progesterone is responsible for maintenance of a pregnancy once fertilization has occurred
- Estrogens increases_____density and increasing HDL cholesterol level
- Estrogen promotes blood coagulation that can lead to formation of blood clots in specific circumstances

- **Uterine cycle (menstrual cycle)** – series of cyclic events that uterine **endometrium** goes through each month
    - Uterine changes are coordinated with estrogen and progesterone levels released during ovarian cycle
- Endometrium is composed of two main layers:

1. _____ (**functional layer**) detaches from uterine wall and is shed usually monthly during **menstruation**

2. _____ (**basal layer**) does not thicken or shed, it replaces stratum functionalis at end of menstruation

1. _____ phase, **days 1–5**: uterus sheds stratum functionalis, resulting in **menstruation**

2. _____ (**preovulatory**) **phase**, **days 6–14**: stratum functionalis thicken; these glands enlarge and veins and arteries increase in number

3. _____ phase, **days 15–28**: arteries form in stratum functionalis and endometrial glands increase

- If pregnancy doesn't occur, cells of stratum functionalis die and on day 28 menstrual phase begins
- If pregnancy occurs, secretory phase continues and uterus continues to develop in preparation for an embryo

Puberty and Menopause

- **Puberty** – typically begins between 9 and 11 years old for females with increase in estrogen and progesterone resulting secondary sex characteristics

- Breasts development begins
- Appearance of pubic and axillary hair and an increase in secretions from sebaceous glands
- _____ tissue increases in subcutaneous layer throughout body, with additional deposits in hips, thighs, and breasts
-

- _____ – first episode of menstrual bleeding; occurs approximately two years after onset of puberty
  - Will not occur unless a girl has at least_____body fat
  - **Leptin** – hormone secreted by adipocytes; stimulates gonadotropin secretion
- _____ – point when menstruation has not occurred for at least one year
  - Number of primary follicles left that can respond to LH and FSH is diminished after thirty or more years of ovarian cycles
- Reduced levels of estrogens and progesterone may alter female secondary sex characteristics
  - Breasts, uterus, and uterine tubes may shrink, while pubic and axillary hair may thin
  -
  - _____ may occur due to changes in rhythmic secretion of GnRH

Cervical Cancer

- **Cervical cancer** occurs most often in women between the ages of 30 and 50
- Frequently caused by human papillomavirus (HPV), which is transmitted sexually

- The number of cases and number of deaths from cervical cancer have decreased significantly; projected to decrease further as **HPV vaccine** becomes more widespread
- Cervical Cancer
- Decline is due in large part to **Pap** (**Papanicolaou**) **smear test**; detects precancerous cells and early-stage cancers before symptoms are noticeable; involves scraping loose cells from cervix and examining them microscopically
- Cells showing signs of abnormal development (**dysplasia**) warrant further investigation, including visual examination of cervix or a **biopsy** to determine if cancerous cells are present

Development and Heredity

Chapter 27

27.1 Overview of Human Development

Prenatal Development

- **Pre-embryonic period** – lasts for first 2 weeks after fertilization; zygote divides that implants in endometrium
- **_____ period** – extends from week 3 through 8 of gestation; **embryo** grows, folds, and forms rudimentary organ systems
- **_____ period** – lasts from week 9 until birth; **fetus** grows larger and continues to develop until its organ systems can function without assistance from mother

27.2 Pre-embryonic Period: Fertilization through Implantation

Fertilization

- Fusion of **sperm cell** and **secondary oocyte** to form a _____

Cleavage and Blastocyst Formation

_____ - series of rapid mitotic divisions that produce genetically identical cells called

At this stage, cells start to differentiate known as a _____

Cell division continues producing a **blastocyst (_____)**:

- An outer layer of cells, called **trophoblast cells**, participate in forming **placenta**
- **Inner cell mass**, or embryoblasts, form embryo

Implantation

Implantation occurs approximately 4 – 7 days after fertilization when blastocyst begins to attach to endometrium

- Trophoblast secretes **human chorionic gonadotropin** (_____)
    - Stimulates corpus luteum in ovary to secrete estrogen and progesterone
    - Progesterone maintains endometrium
    -

Development of Extraembryonic Membranes

Extraembryonic membranes first appear during second week of development, continue to develop during embryonic and fetal periods

- Protecting embryo
- Nutrition uptake
- Gas exchange
- Storage and removal of waste
-
    - Encloses embryo in fluid-filled **amniotic cavity**; penetrated only by **umbilical cord**
    - Secretes **amniotic fluid** into cavity
    - Protects embryo from trauma and drying out
- _____ – outermost extraembryonic membrane
    - Forms _____

Ectopic Pregnancy

- In an **ectopic pregnancy**, implantation and growth in any location other than endometrium (1–2% of all pregnancies are ectopic)
- Almost all of these are "**tubal pregnancies**" but can occur in other locations (abdominal cavity, ovary, or cervix)
- Presents a large risk to mother, as only uterus is able to expand and sustain the pregnancy

27.3 Embryonic Period: Week 3 through Week 8

Embryonic Period

- **Embryonic period** - starts with formation of _____
- Three germ layers develop during this period that will become all of major organ systems in process of _____
  - Placenta forms during this period and begins to provide nutrition and oxygen to embryo and remove wastes

27.4 Fetal Period: Week 9 until Birth (about Week 38)

Placentation

- **Placentation** – formation of placenta; attaches to uterine wall and to embryo/fetus through umbilical cord
- _____ – organ that is shed after infant is born develops from both fetal (chorionic villi) and maternal (decidua basalis) structures
  - Site of exchange of oxygen, nutrients, and waste between mother and fetus
  - Produces hormones to support pregnancy
  -

- **Umbilical cord** connects center of placenta to fetus **umbilicus**
  - _____ - carry deoxygenated to placenta
  - _____ **-** carries oxygen and nutrients toward fetal
  - Deoxygenated fetal blood in umbilical arteries → placenta into chorionic villi
  - Fetal blood then picks up oxygen and nutrients and delivers waste by diffusion
  - Oxygenated blood leaves placenta → umbilical vein
  - **Fetal circulation** and **cardiovascular system**
  - Unique cardiovascular structures present during prenatal development:

    umbilical arteries

    umbilical vein

    3 vascular shunts
    - Blood from umbilical vein bypasses liver via_____; connected to inferior vena cava and flows into right atrium of heart
    - _____ – hole in interatrial septum that directly connects right and left atria; bypasses lungs
    - _____ – short passage that connects pulmonary trunk to aorta; bypasses lungs

Premature Infants

- An infant is considered **premature** if it is born more than 3 weeks before full-term (38 weeks); more than 12% of babies born in United States each year are premature

- The earlier the birth, the more complications infant is likely to experience; most commonly, premature infants suffer from respiratory, digestive, and thermoregulatory difficulties

Module 27.5 Pregnancy and Childbirth

Changes during Pregnancy

- **First trimester** (**months 1–3**) pre-embryonic and embryonic development is completed and fetal development begins
    - By end of first trimester, basis of all of major organ systems are present making it most critical stage of development
- **Second trimester** (**months 4–6**) fetus continues to grow and develop; pregnancy usually becomes obvious as uterus and abdomen expand
    - Ossification begins in most bones
    - Genitals are distinguishable as male or female
    - Heartbeat can be heard with a stethoscope
    - _____ and _____ present
    - Skeletal muscles begin to contract
- **Third trimester** (**months 7–9**) fetus grows rapidly and gains a significant amount of weight
    - Woman's uterus and abdomen enlarge further and many women exhibit new symptoms related to size of the fetus
    - Eyelids open completely
    - Fetus usually turns upside down
    - In males, testes begin to descend through inguinal canal
    - Fetal neurons form networks

Placenta also functions as an endocrine organ:

-

- Corpus luteum relinquishes production of progesterone and estrogens to placenta by end of third month of gestation
- **Human placental lactogen** and **placental prolactin** - prepare mammary glands for milk production
- **Relaxin** - relaxes body's muscles, joints, and ligaments

-

-

- **Oxytocin** from fetal and maternal hypothalamus is secreted during second and third trimesters and peaks during labor to stimulate uterine contractions and allow milk release from mammary glands

Childbirth (Parturition)

- Series of events collectively called **labor**
  - Both fetal and maternal hypothalamus secrete oxytocin; stimulates placenta to secrete prostaglandins
  - Prostaglandins dilate cervix and with oxytocin, increase strength of uterine contractions
    - As head of fetus pushes on and stretches cervix, more oxytocin is released
    - As more oxytocin is released, myometrium contracts more forcefully and placenta secretes more prostaglandins
    - Both effects cause cervix to stretch more, which stimulates release of more oxytocin (_____)

Prenatal and Newborn Genetic Screening

- Cells and amniotic fluid may be withdrawn and analyzed to test for chromosomal abnormalities.
- Usually recommended for women 35 years or older at delivery, as their oocytes are older; increases risk of chromosomal abnormalities; also recommended for women who know they or father are carriers of inherited diseases, or when possible fetal abnormalities are discovered on ultrasound
    - _____ – done between 14 and 20 weeks of pregnancy; amniotic fluid is withdrawn using a needle inserted into amniotic cavity, as shown
    - _____, withdraws chorionic villi tissue