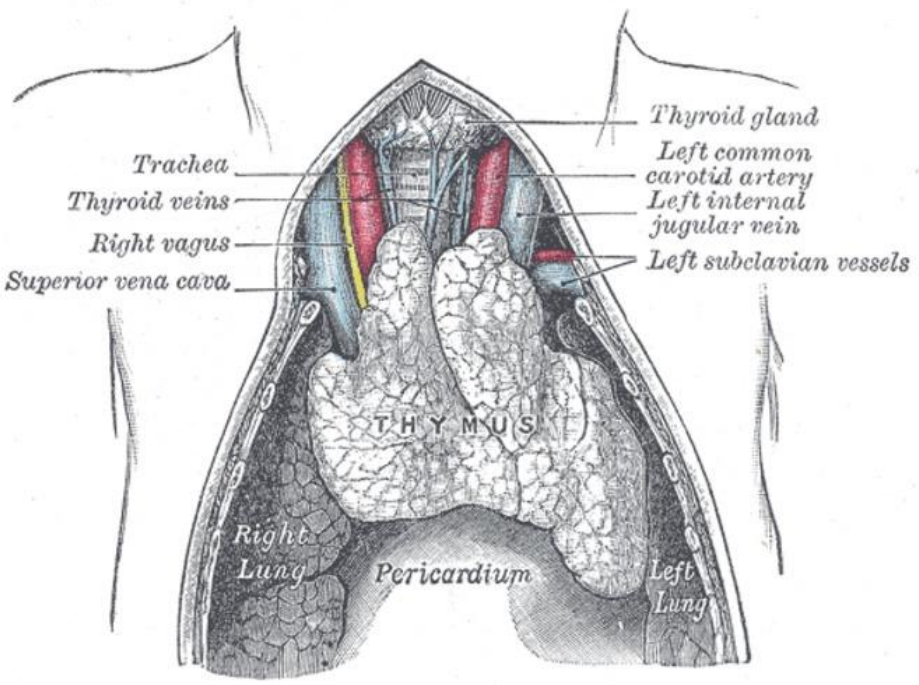
Biology 211
Human Anatomy & Physiology II
Lecture Coursepack

For January 2020
(Last Updated Aug 2017)



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BIOLOGY 211
LECTURE COURSEPACK

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Chapter numbers refer to Anatomy and Physiology by Erin Amerman, 1st Edition

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Chapter 16: Endocrine System

Endocrine System Functions

1. Coordinates and directs the body's activities
2. Works in conjunction with the nervous system.

   *Which system is faster?*_____

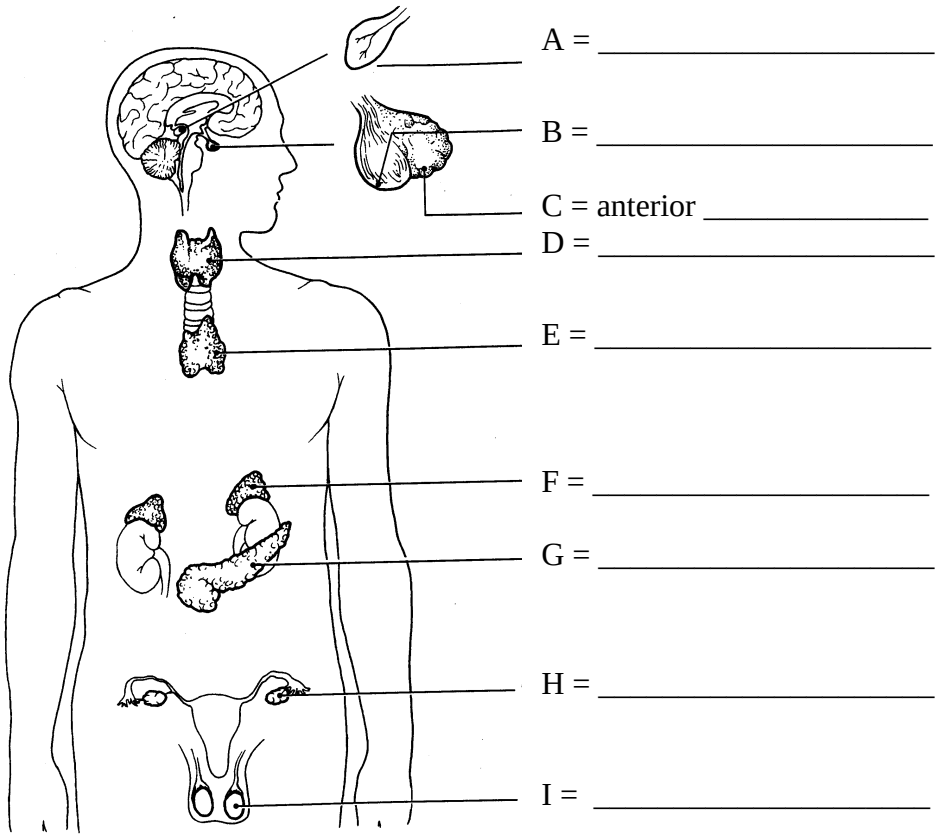
   Which system is slower? _____

3. Uses chemical messengers called *hormones*. In contrast, *neurotransmitters* are released by neurons into synapses of target tissues while hormones travel via the blood stream to target tissues.

What are some differences between endocrine and exocrine glands?

Endocrine Glands	Exocrine Glands
Lack ducts	Have ducts that transports substances
Secrete hormones directly into the blood stream	Excretes substances onto an epithelial surface like skin
Examples: pituitary, thyroid, parathyroid, adrenal, pineal, thymus	**Examples**: sweat, oil, tear, mammary glands
Some organs are also endocrine glands such as pancreas and gonads	
Other tissues and organs produce hormones such as small intestine, stomach, kidneys, heart	

Major Endocrine Glands



Chapter 16: Endocrine System, Continued

Hormone Functions

Hormones are chemical messengers that travel the blood stream and influence the activity of their target cells. Hormones travel in the bloodstream. Other chemical messengers, like neurotransmitters, travel over a nervous system pathway.

What are the mechanisms for hormone activation of a target cell? For a target cell to respond to a hormone it must have *specific receptors* to which it can bind.

How do hormones arouse their target cells?

1. **Secondary Messenger System (Cyclic AMP Signaling Mechanism)**

Which hormones operate this way? *water-soluble hormones* such as protein, peptide, and most amine hormones bind to receptors on the *plasma membrane* of their target cells. These hormones cannot enter the cell, so they have to change the cell's activities using this messenger system.

a. **First messenger=**the hormone. The hormone binds a receptor on the plasma membrane, causing increased synthesis of cyclic AMP (cAMP) from within the cell.

b. **Second messenger** = cAMP, which activates or deactivates enzymes called **protein kinases**. In turn, protein kinase causes specific physiological changes to occur in the target cell such as a faster rate of mitosis.

Example: TSH promotes synthesis of thyroxine (TH); GH causes proteins to be built in bones and muscles.

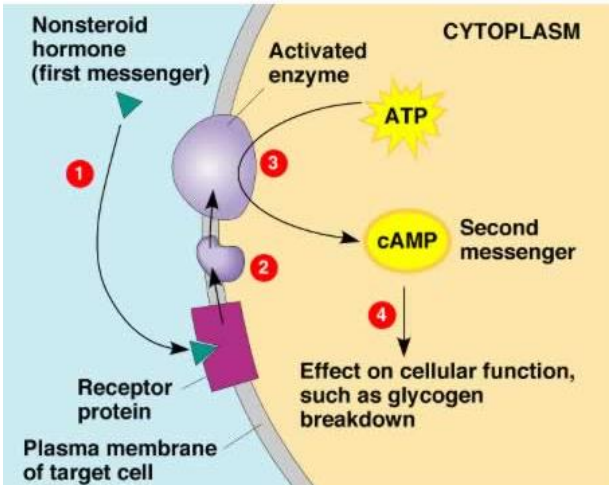
2. **Direct Gene Activation**

Which hormones operate this way? *lipid-soluble hormones* (steroid hormones) and thyroid hormone (*oddly*, a protein hormone)

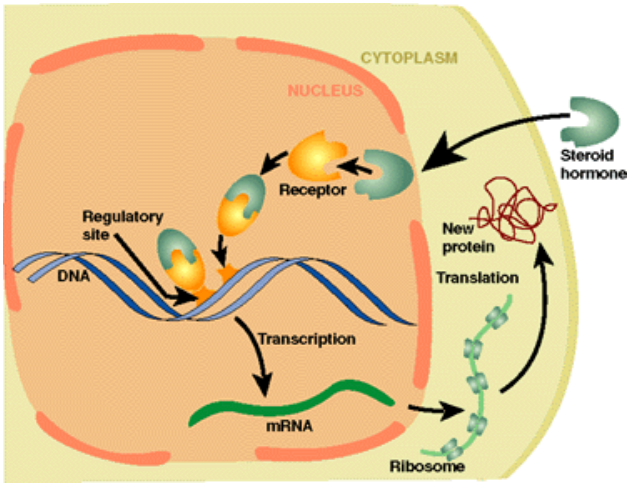
a. Lipid hormones diffuse into the target cell and bind an _____ **receptor**.

b. Then, the hormone travels to the nucleus. There, the receptor-hormone complex binds with a region of DNA.

c. Protein synthesis is activated; transcription and translation occur and **proteins** are made.



Secondary Messenger System



Direct Gene Activation

Chapter 16: Endocrine System, Continued

Hormone Interactions

1. **Permissiveness**: one hormone has to be present in other for the other one to do its job

   Example: thyroid hormone must be present for sex hormones to cause effects

2. **Synergism**: hormones work together to produce the same effect

   Example: glucagon and adrenaline both cause an increase in blood sugar levels

3. **Antagonism**: hormones perform opposite actions of one another

   Example: insulin lowers blood glucose levels while glucagon raises blood glucose levels

Three Major Types of Stimuli Cause Endocrine Glands to Release their Hormones

Humoral Stimuli	Neural Stimuli	Hormonal Stimuli
Hormones are released in response to blood concentration of ions or nutrients	Hormones are released in response to stimulation from the nervous system	Hormones are released in response to other hormones from another endocrine gland
Calcitonin, parathyroid hormone, insulin, glucagon, aldosterone	*Epinephrine and oxytocin*	*Thyroid releasing hormone triggers the release of thyroid stimulating hormone which triggers the release of thyroid hormone*

Review of Hormonal Release

Determine if each of the following describes:

A. humoral control
B. neural control
C. hormonal control

_____1. TSH activates the release of thyroid hormone
_____2. Calcitonin is released in response to high blood calcium levels
_____3. Epinephrine travels along a sympathetic pathway
_____4. ACTH activates the release of hormones from the cortex of the adrenal gland
_____5. A decrease in blood glucose level leads to the release of glucagon
_____6. GHRH activates the release of growth hormone

Answers: 1C, 2A, 3B, 4C, 5A, 6C

This page is commonly missed on tests! Flash cards work great! Include the hormone, where it's produced, its target organ, and its action.

Chapter 16: Endocrine System, Continued

Control of Hormone Release

- Hormonal secretion is regulated to limit over- or under-production of a particular hormone.
- The synthesis and release of most hormones is regulated by some type of *negative* feedback system**.** The hormone is produced until the amount needed for the desired effect is reached, then production is shut off (like a thermostat).
- **HYPOTHALAMUS**

1) Releases hormones to control the production of hormones from the anterior pituitary. These hormones are known as "releasing hormones" or "inhibiting hormones."

Releasing hormones *stimulate* the release of a particular hormone by the **anterior** pituitary.

- Growth hormone releasing hormone (GHRH)
- Corticotropic releasing hormone (CRH)
- Thyrotropic releasing hormone (TRH)
- Gonadotropic releasing hormone (GnRH)
- Prolactin releasing hormone (PRH)

Inhibiting hormones *decrease* the release of a particular hormone by the **anterior** pituitary.

- Growth hormone inhibiting hormone (GHIH)
- Prolactin inhibiting hormone (PIH)

2) Makes two hormones that are released from the posterior pituitary (ADH and OXY). The posterior pituitary does not make its own hormones.

- Oxytocin (OXY)
- Antidiuretic hormone (ADH)

- **PITUITARY GLAND ("Hypophysis")**

Anatomy: The pituitary is a pea sized gland connected by a stalk, called the infundibulum, to the hypothalamus. The pituitary gland lies in a depression of the sphenoid bone called the sella turcica. A portal (blood) system carries hormones from the hypothalamus to the anterior pituitary gland.

Two major lobes

1. The **anterior pituitary** ("**adenohypophysis**") is made up of endocrine tissue. This portion releases **tropic hormones**. Tropic hormones elicit a response in another gland or organ, often causing them to release hormones. The anterior pituitary makes and releases these six protein hormones:

- Growth hormone (GH)
- Thyroid stimulating hormone (TSH)
- Adrenocorticotropic stimulating hormone (ACTH)
- Gonadotropic hormones
  - Follicle stimulating hormone (FSH)
  - Luteinizing hormone (LH)
- Prolactin (PRL)

Chapter 16: Endocrine System, Continued

Hypothalamus-Anterior Pituitary Relationship

Control of Growth Hormone	Control of Thyroxine	Control of Adrenal Gland (Cortex) Hormones
To increase GH production Hypothalamus produces GHRH ⇩ GHRH targets the anterior pituitary ⇩ Anterior pituitary produces GH ⇩ GH targets the body's cells ⇩ Body cells grow (enlarge in size) *What role does GHIH play?* _____ _____ *What is the cause of gigantism, acromegaly, and pituitary dwarfism?* _____	**To increase thyroxine production** Hypothalamus produces TRH ⇩ TRH targets the anterior pituitary ⇩ Anterior pituitary produces _____ ⇩ TSH targets the thyroid gland ⇩ Thyroid gland produces thyroxine	**To increase adrenal production** Hypothalamus produces CRH ⇩ CRH targets the anterior pituitary ⇩ Anterior pituitary produces ACTH ⇩ ACTH targets the adrenal gland ⇩ Adrenal gland produces hormones like aldosterone, cortisol, & sex hormones

Control of FSH/LH	Control of Prolactin
To increase FSH/LH production Hypothalamus produces GnRH ⇩ GnRH targets the anterior pituitary ⇩ Anterior pituitary produces FSH/LH ⇩ FSH/LH targets the _____ (ovaries/testes) ⇩ FSH promotes hormones production (testosterone by testes; estrogen by ovaries) LH promotes formation of sex cells (sperm by testes; ova by ovaries)	**To increase PRL production** Hypothalamus produces _____ ⇩ PRH targets the _____ pituitary ⇩ Anterior pituitary produces PRL ⇩ PRL targets the mammary glands ⇩ Mammary glands produces milk *What role does PIH play?* _____ _____

Chapter 16: Endocrine System, Continued

Hypothalamus-Posterior Pituitary Relationship

Two major lobes, continued

2. The **posterior pituitary** is made of nervous tissue. It stores 2 hormones made by the hypothalamus and releases those hormones upon neural stimulation. The posterior pituitary **makes no hormones of its own**.

Hormone	Control	Function	Target Organ	Disorders
Oxytocin (OXY)	Neural	In a female giving birth, uterine contractions In a breast-feeding female, the mammary glands eject milk (milk let-down reflex)	Uterus and Mammary glands	
Antidiuretic hormone (ADH) (vasopressin)	Humoral – osmoreceptors monitor how salty the blood has become. They stimulate the hypothalamus to release ADH from vesicles stored in the axon terminals in the posterior pituitary	ADH promotes water retention (kidneys) ADH increases blood volume and pressure ADH prevents dehydration	Kidney tubules	**Alcohol** suppresses ADH production; urine output is increased and dehydration is a risk. **Diabetes insipidus** results from hyposecretion of ADH and causes these signs/symptoms: 1) urine output (polyuria) 2) polydipsia 3) dehydration Patients with diabetes insipidus have NO problems with blood sugar levels and NO polyphagia (increased hunger).

Review of the Pituitary Gland

1. GH hormone levels are low. Which hormone will promote the release of GH? _____
2. What is the target organ of PIH? _____
3. How does alcohol affect the release of ADH? _____
4. Which two hormones are associated with milk letdown and production by females? _____
5. What effect does TRH have on TSH levels? _____
6. The adrenal cortex responds to the hormone known as: _____
7. What effect does ADH have on blood pressure? _____
8. The two hormones secreted by the posterior pituitary are made by the _____

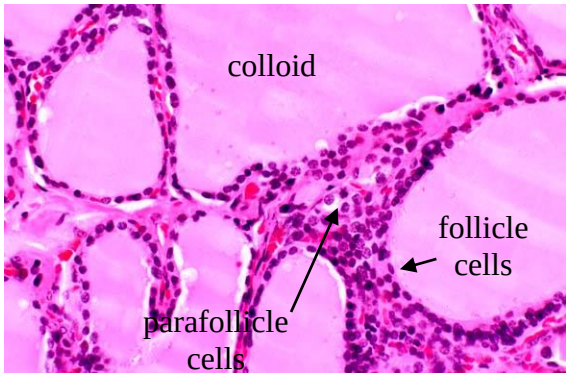
Answers: 1-GHRH, 2-anterior pituitary gland, 3-inhibits release, 4-PRL (production) and oxytocin (milk letdown "reflex"), 5-increases levels, 6-ACTH, 7-retains water and in turn, increases blood pressure, 8-hypothalamus

Chapter 16: Endocrine System, Continued

THYROID GLAND

Anatomy

- Butterfly-shaped gland located at the base of the trachea. Two lobes are joined by a central mass (isthmus)
- Thyroid is the largest pure endocrine gland in the body; has a rich blood supply.
- **Follicle cells** make _____ hormone
- **Parafollicular cells** make _____.
- **Colloid** (gel-like substance) stores thyroid hormone (30 days).



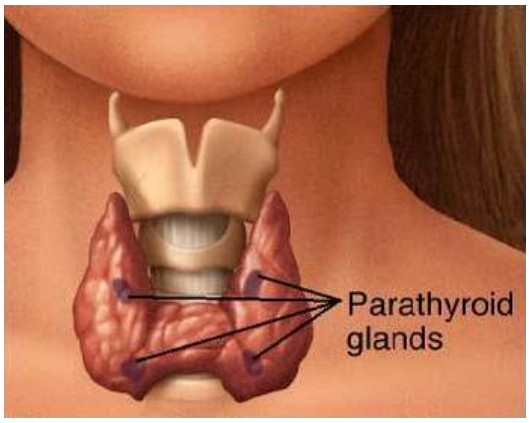
THYROID GLAND HORMONES

Hormone	Control	Function	Target Organ	Disorders
Thyroid Hormone (TH) **Thyroxine** is made by the thyroid follicles (T_4 due to 4 Iodine atoms) **Triiodothyronine** is made from the conversion of T_4 to T_3 at the body's cells (T_3 due to 3 Iodine atoms)	hormonal TRH → TSH → TH Normal TSH levels vary but are often between 0.3 and 3.0 µU/mL (used as an indicator for thyroid function)	1) Regulation of **metabolism** (stimulates carb and lipid metabolism in most cells); raises body temperature. 2) Regulation of **development** during childhood years (skeletal, nervous, and reproductive systems	all body cells	**Hypothryoidism** (>3.0) – **Myxedema** – Severe hypothyroidism as an adult. *Symptoms*: weight gain, low BMR, sluggishness, mental fog, puffy eyes, hair loss **Cretinism** (Congenital Hypothyroidism) – Severe hypothyroidism from birth. *Symptoms*: low BMR, thick skin, mental retardation, stunted growth **Goiter** – lack of iodine in the diet or iodine metabolism disorder. *Symptoms:* thyroid gland enlarges around neck/trachea. Similar symptoms to hypothyroidism (usually) **Hyperthyroidism** (Graves Disease) (<0.3) – with *exophthalmos*. *Symptoms*: high BMR, weight loss, intolerance to heat, fast heart rate, hair loss, anxiety, insomnia
Calcitonin	humoral Calcitonin is released when blood calcium levels are *high* (hypercalcemia). In other words, hypercalcemia triggers calcitonin release.	1) Decreases blood calcium levels by causing calcium to be deposited to the bones. 2) Stimulates osteoblasts to take calcium from the blood and deposit it into the bone matrix. Inhibits osteoclasts.	bones	

Chapter 16: Endocrine System, Continued

PARATHYROID GLANDS

Anatomy: (*para* = around) tiny masses of glandular tissue found on posterior surface of thyroid gland. There are usually 4 glands, with 2 attached to each lobe of the thyroid, but the number may vary (as many as 8 have been reported). This gland regulates itself (*humoral control*).



Parathyroid Hormone (PTH) is secreted by the parathyroid (chief) cells of the parathyroid gland.

Functions: PTH is released in response to *LOW* blood calcium levels. PTH increases blood calcium levels (Ca^{+2}) by stimulating 3 target organs.

Target organs:

1. **Bone:** PTH stimulates osteoclasts to break down bone matrix, releasing calcium ions into the blood.
2. **Kidneys:** PTH causes increased reabsorption of Ca^{+2} back into the blood.
3. **Small intestine:** PTH increases absorption of Ca^{+2} by intestinal mucosal cells.

Control of secretion? *Humoral control.* PTH release is triggered by low blood calcium levels, and inhibited by **hypercalcemia**. The overall effect of PTH is to increase blood calcium level.

Disorder: Excess PTH causes **hyperparathyroidism**. This condition leads to excess calcium in the blood, a condition called **hypercalcemia**.

- Which hormone acts as an **antagonist** to PTH? _____

Chapter 16: Endocrine System, Continued

Review of the Thyroid Gland

1. Which specific thyroid hormone is formed at the target cells?_____
2. Lack of iodine in the diet can cause an enlargement of the thyroid gland known as _____
3. Low TSH levels will stimulate this hormone, _____, to stimulate the release of TSH.
4. What do low levels of T_4 do to the levels of TSH in the bloodstream? _____
5. What role does TRH play in regulating the thyroid hormone?_____
6. What effect does calcitonin have on blood calcium levels? _____
7. Which special cells of the thyroid gland release TH? _____ and calcitonin?_____
8. How many iodine atoms are found in T_3? _____
9. A person takes a radioactive pill containing iodine. Which cells of the thyroid gland take up the iodine? _____
10. A person whose thyroid gland has been removed has difficulty maintaining calcium levels. Why?
11. Why test for TSH when monitoring thyroid gland functioning?
12. Here are some recent lab results: Patient #1, TSH = 5.4; Patient #2, TSH = 2.9; Patient #3, TSH = 0.1

Who is hypothyroid? Who has a normal TSH? And, who is hyperthyroid?

13. If someone has a thyroidectomy, why do you think calcium supplements might be necessary for life?

Answers:
1. T_3; 2. endemic (colloidal) goiter; 3. TRH; 4. Low levels of T_4 would stimulate increased levels of TSH; 5. TRH causes the release of TH from the thyroid gland; 6. Calcitonin lowers blood calcium levels by depositing excess calcium to bones; 7. TH is made by follicle cells (follicular) and calcitonin is made by the parafollicular cells; 8. There are 3 Iodine atoms; 9. follicle or follicular cells; 10. Thyroid gland also makes calcitonin which lowers calcium levels of the blood. Also, parathyroid glands may have been removed since it also controls calcium levels of the blood through parathyroid hormone; 11. TSH is secreted in response to low thyroid hormone levels in the blood. If TSH is high (towards 3.0), then there is not enough TH in the blood and the person is approaching hypothyroidism; if TSH is low (towards 0.3), then there could be too much TH in the blood and the person is approaching hyperthyroidism. TSH indicates thyroid gland response; 12. Hypothyroid is Patient #1, Normal TSH is Patient #2, Hyperthyroid is Patient #3; 13. Removal of the thyroid means no production of calcitonin; also parathyroid glands could have been removed as well

Review of the Parathyroid Glands

1. Which hormone is an antagonist to PTH?_____
2. Which hormone activates osteoclasts to raise blood calcium levels?_____
3. Which hormone lower blood calcium levels by activating osteoblasts?_____
4. Which hormone stimulates the kidneys to increase absorption of calcium into the blood? _____
5. Which hormone, do you think, would be most active when a mother breastfeeds? _____

Answers: 1. Calcitonin, 2. PTH, 3. Calcitonin, 4. PTH, 5. PTH because calcium is needed for breast milk.

6. Why would a person with hypoparathyroidism have frequent muscle spasms or tingling in the fingers and toes?
7. Why might a person with hyperparathyroidism have weak, brittle bones?
8. Why do you think that hypercalcemia would be a sign of a PTH disorder? And, what type of disorder would it indicate (*hyper* or *hypo*?)

Answers: 6. Hypoparathyroidism means low PTH. Low PTH means hypocalcemia. These symptoms are for hypocalcemia. 7. Hyperparathyroidism means high PTH. High PTH means hypercalcemia (too much calcium in blood). That calcium is taken from the bones. 8. Hypercalcemia means blood calcium levels are too high; overactive parathyroid. This would be hyperparathyroidism.

Chapter 16: Endocrine System, Continued

ADRENAL GLANDS

Anatomy: (*ad* = toward, *renal* = kidney*)* these glands sit on tops of the kidneys.

Contains **two** main portions: *adrenal cortex* and *adrenal medulla*

1. **Adrenal cortex** encloses the medulla portion and is made of endocrine (glandular) tissue. (SUPERFICIAL). This portion of the adrenal gland makes steroid hormones. Ultimately controlled by 1) CRH - hypothalamus & 2) ACTH - anterior pituitary gland.

The three layers all make steroid hormones**:**

a. **Zona glomerulosa**, superficial layer, makes **mineralocorticoids**.

b. **Zona fasciculate,** middle layer, makes **glucocorticoids**.

c. **Zona reticularis,** deepest layer, makes **gonadocorticoids**.

2. **Adrenal medulla** is made of nervous tissue. (DEEP)

Adrenal Cortex Hormones

1. **Mineralocorticoids** are produced by the outer layer of the adrenal cortex. The main mineralocorticoid is **aldosterone**, which targets the kidney.

Functions of aldosterone:

a. Regulates blood pressure.

b. Regulates blood concentrations of Na^+ ions, K^+ ions, H^+ ions, bicarbonate ions…and water indirectly

Target organ: kidney

How is aldosterone secretion or release controlled?

- *Renin-angiotensin mechanism* (<u>most important regulator</u>):* low blood pressure (the *stimulus*) is detected by the kidneys. The kidneys release renin. Renin travels to the liver to stimulate the release of angiotensin I and II. Angiotensin II triggers the adrenal cortex to release aldosterone. Aldosterone targets the kidney to retain water & sodium. Blood pressure increases.
- *Humoral control (Blood plasma concentrations of sodium and potassium)*
  - An INCREASE in potassium levels **stimulates** the release of aldosterone
  - A DECREASE in potassium levels **inhibits** the release of aldosterone (*K+ is an intracellular cation)*
  - A large decrease in sodium cause a *slight* increase in aldosterone release
- *Hormonal control***:** ACTH has little or no effect on aldosterone release, but under stress, the hypothalamus causes an INCREASE in aldosterone levels.

What if blood pressure is too high? How can it be reduced?

- **ANP** (atrial natriuretic peptide) is a hormone secreted by the heart when blood pressure increases. It acts to decrease water, sodium, and fat loads on the circulatory system to decrease BP.
- ANP is an **antagonist** to aldosterone.

Chapter 16: Endocrine System, Continued

ADRENAL GLANDS, continued

Adrenal Cortex Hormones, continued

2. **Glucocorticoids** are produced by the middle layer of the adrenal cortex (called *zona fasciculata*). The main hormone is **cortisol** (hydrocortisone), a type of steroid hormone.

Functions:

a. **Gluconeogenesis:** breaks down fats & proteins into **glucose** for energy.
b. Break down of protein (into **amino acids**) to be remade into enzymes needed for metabolism.
c. Provide resistance to stress
d. Anti-inflammatory - lowers the immune response.

Excess cortisol has anti-inflammatory and anti-immune effects (*so we get sick*) and raises blood sugar (*we get fat*)

Control of secretion? CRH (hypothalamus) → ACTH (anterior pituitary) → cortisol (made by adrenal cortex)

3. **Sex hormones (Gonadocorticoids)** are produced in small amounts by the adrenal cortex (*zona reticularis).* Most of the gonadocorticoids are weak androgens (male sex hormones). These hormones are converted in males to testosterone and in females to estrogen. Since the amounts produced here are so small, their role is still in question.

Disorders of the Adrenal Cortex Hormones

Addison's disease

Cause: hyp____secretion of aldosterone and/or cortisol

Symptoms: weight loss, low blood pressure, bronzing of the skin, pica (cravings for dirt, baking soda, matches), muscle fatigue, tiredness

Cushing's disease

Cause: hyp___secretion of cortisol

Symptoms: weight gain (quick!), high blood pressure, irritability, anxiety, depression, hirsutism (growth of hair in a male pattern), stretch marks (striae), moon face, buffalo hump (excess brown fat between the shoulder blades), bronzing of the skin

Masculinization in women (adrenogenital syndrome)

Cause: hypersecretion of male sex hormones (androgens) produced by the adrenal cortex

Symptoms: male patterns of hair growth on the face, chin, neck, or chest; deeper voice

Chapter 16: Endocrine System, Continued

ADRENAL GLANDS, continued

Adrenal Medulla Hormones

The adrenal medulla is part of the autonomic nervous system. "*Fight or flight response"* mobilizes the *sympathetic nervous system.* The hormones secreted by the adrenal medulla are called *catecholamines:*

1. **Epinephrine** ("epi" or adrenaline)
2. **Norepinephrine** ("NE" or noradrenaline)

Both **epinephrine** and **norepinephrine** stimulate the "fight or flight response." These hormones cause:

- ↑ blood glucose levels
- ↑ mental alertness, metabolism
- ↑ heart rate, blood pressure, dilate respiratory passageways and increase bronchiole diameter
- ↑ blood flow to brain and skeletal muscles
- ↓ GI activity and urinary activities

Control of secretion? under stress (**neural control**), sympathetic preganglionic neurons stimulate the chromaffin cells in the adrenal medulla to secrete epinephrine and norepinephine. Unlike adrenocortical hormones, these from the medulla are NOT essential for life.

For Discussion of the Adrenal Glands

1. How would a high salt (sodium chloride) diet affect aldosterone release?
2. How would a stressful lifestyle affect cortisol release?
3. How would an adrenal cortex tumor affect sex hormone release in a female? What symptoms might she experience?
4. Are epinephrine and norepinephrine necessary for life?
5. How would high levels of aldosterone affect sodium and potassium levels in the blood?
6. Which hormones are produced by each *zona* of the adrenal cortex?
7. What effect would a pituitary gland tumor have on the adrenal glands?
8. Why would someone taking cortisone for a long time experience muscle loss?
9. People in the hospital for heart failure are often issued meals with no salt added. Why do you think this is done?
10. How does ANP respond to high blood pressure?
11. Why would an increase in sodium cause an increase in water retention?
12. Why does a person with increased stress often have high blood pressure—and how could cortisol play a role?

Answers: 1. High levels of salt would inhibit aldosterone release to cause the body to not reabsorb sodium. 2. Stress increases cortisol release to maintain normal metabolism by breaking down stored fats and proteins. 3. An adrenal cortex tumor would increase the levels of sex hormone release in a female possibly resulting in masculinization. 4. No, these hormones are not necessary for life. 5. High aldosterone levels increase reabsorption of sodium (salt) and loss of potassium by the kidneys, resulting in an electrolyte imbalance. 6. *See previous pages.* 7. A pituitary tumor would increase ACTH levels, in turn increasing levels of adrenal cortex hormones. 8. Cortisone causes breakdown of both fats and proteins to turn into energy. 9. Remove salt from the diet and the person will retain less water (of course, ADH will retain water if blood becomes too "salty.") 10. ANP promotes the loss of fat, sodium, and water in an effort to reduce blood pressure. It works against aldosterone. 11. Water follows salt! Water is retained if sodium is retained by the kidneys. 12. Stress triggers ACTH release. Cortisol is responsible for providing resistance against long-term stresses by increasing sugar and amino acids in the blood.

Chapter 16: Endocrine System, Continued

PANCREAS

Anatomy: The pancreas is close to the stomach in the abdominal cavity. Masses of hormone and enzyme producing tissues are mixed (the pancreas is both an endocrine gland and an accessory digestive organ)

- Pancreatic islets (*islets of Langerhans*) are the part of the pancreas that produce 2 glucose-regulating hormones
- Insulin is produced by the **BETA** cells of the pancreatic islets while glucagon is produced by **ALPHA** cells.
- The pancreas operates under *humoral* control.

Pancreas Hormone	Control	Function	Target Organ
Insulin	humoral – in response to blood sugar (glucose) levels	1) Influences the liver to store glucose as glycogen (**glycogenesis**) when blood sugar levels are high 2) Pushes sugar into cells for making ATP	Liver, skeletal muscles Body cells
Glucagon	humoral – in response to blood sugar (glucose) levels	1) When blood sugar levels are low, glucagon targets the liver & skeletal muscles to break down glycogen into glucose (**glycogenolysis**)	Liver, skeletal muscles

Diabetes mellitus

Cause: hyposecretion of insulin by the beta cells of the pancreatic islets *or* the cells of the body have become insulin-resistant. Blood sugar levels become elevated and excess blood sugar is lost in the urine.

Three cardinal signs:

1) _____

2) _____

3) _____

Other signs/symptoms: nausea, vomiting, **ketosis** and perhaps **ketoacidosis** (break down of fats into glucose). The body doesn't think there's enough sugar when blood sugar becomes so high, so fats are broken down to make sugar. Ketoacidosis causes the breath to take on a fruity odor like acetone (typically with Type I more so than Type II).

Long term problems: neuropathy, blindness, kidney failure

Type I (Juvenile Diabetes or Insulin-Dependent Diabetes Mellitus = IDDM)

This type of diabetes makes the patient dependent on insulin injections.

Type 2 (Adult-Onset Diabetes or Non-Insulin Dependent Diabetes Mellitus = NIDDM)

This form of diabetes can be controlled by diet, medication, and/or exercise.

Gestational Diabetes (during pregnancy)

Chapter 16: Endocrine System, Continued

Read this page as homework.

PINEAL GLAND

Anatomy: The pineal gland is located in the brain in the area of the third ventricle and diencephalon. It releases melatonin, the "sleep" hormone.

Melatonin

- Melatonin is a hormone released during day and night. The levels vary over a 24 hour period.
- Peak amount of melatonin in blood occurs at night to make us sleepy.
- Lowest levels occur during daylight around noon.
- Melatonin helps establish body's day and night cycle; mating behavior and rhythms in humans.

THYMUS GLAND

Anatomy: The thymus gland is located in the upper thorax, posterior to the sternum. It's larger when younger in life; it shrinks and becomes fibrous connective tissue by old age. It releases thymosin.

Thymosin

- Thymus gland acts as an incubator during childhood for a group of white blood cells, called the T lymphocytes.
- T lymphocytes (also called T cells) circulate in the blood stream and are involved in developing immunity.

For Discussion of the Pancreas, Pineal Gland, and Thymus Gland

1. Michelle has Type I diabetes mellitus. She has heard that her pancreas doesn't work at all. Did she receive correct information? Explain.
2. People who travel west to east can experience jet lag and exhaustion. One solution is to have the traveler sit in front of a light box once he or she has arrived in the new location. Why might this work? What hormone is being "reset"?
3. Why do you think people may be more depressed (Seasonal Affective Disorder, or SAD) during the short, dark days of winter time?
4. Joe has diabetes insipidus. Why does he not worry about taking insulin?
5. What are the three classic symptoms of diabetes mellitus? Which symptom is not associated with diabetes insipidus?
6. Grandpa has to use the restroom frequently to urinate. He also loves to eat candy. Can you be positive he's a diabetic (mellitus)? How could you confirm or rule out diabetes?

1. She did not receive correct information. Type I results from hyposecretion of insulin from the beta cells of the pancreas. 2. Light is necessary for melatonin levels to function normally. 3. Again, melatonin is dependent on light exposure; short, dark days affect the amount of light received through the eyes. 4. Diabetes insipidus is an ADH disorder – this form of diabetes has no problems with sugar levels in the blood (or urine). 5. Polyuria, polyphagia, and polydipsia. For people with diabetes mellitus, frequent urination occurs due to the loss of glucose – water follows glucose and leaves the kidney in the urine – explaining polyuria. Polyphagia occurs because glucose is lost in the urine and needs to be replaced, so hunger results. Last, polydipsia occurs because fluids are lost in the urine and need to be replaced. For people with diabetes insipidus, they would not experience polyphagia since glucose is not lost in the urine and hunger does not result from this form of diabetes. 6. He may be a diabetic, but we can confirm it through testing fasting blood glucose levels (and see if there's glucose in the urine).

Chapter 16: Endocrine System, Continued

Review of the Endocrine System Glands, Hormones, & Actions

(No answers provided here—but there are answers online)

Name of Hormone	**What gland releases it?**	**Action**	**Regulated by:** (stimulating hormone? inhibiting or releasing hormone? humoral control? etc…)
GH			
TSH			
ACTH			
FSH			
LH			
Prolactin (PRL)			
Antidiuretic Hormone (ADH)			
Oxytocin (OXY)			
Thyroxine (T4) Triiodothyronine (T3)			
Calcitonin			
PTH			
Mineralocorticoids Aldosterone			
Glucocorticoids Cortisol/Cortisone			
Gonadocorticoids			
Epinephrine			
Norepinephrine			
Insulin			
Glucagon			
Melatonin			
Thymosin			

Chapter 16: Endocrine System, Continued

Review of the Endocrine System Glands, Hormones, & Actions

(No answers provided here—but there are answers online)

Hormones that regulate calcium

_____ (raises blood calcium)
_____ (lowers blood calcium)

Hormones that regulate sugar levels (glucose)

_____ (lowers blood sugar)
_____ (raises blood sugar)
_____ (maintains sugar levels during long term stresses)
_____ (immediate release for action during "fight-or-flight")

Composition of urine

_____ (water retention by kidneys)
_____ (sodium or salt levels in the blood)

Milk production in females

_____ (milk reflex)
_____ (maintenance of milk production)

Bone composition

_____ (causes lengthening of bones and skeletal muscles)
_____ (causes calcium to be deposited to bones)
_____ (causes calcium to be removed from bones)

Metabolism

_____ (regulates metabolism)
_____ (promotes normal metabolism during long term stresses)

Diabetes

Hyposecretion of _____→ diabetes insipidus
Hyposecretion of _____→ diabetes mellitus

Graves Disease

Hypersecretion of _____

Giantism

Hypersecretion of _____as a child

Dwarfism

Hyposecretion of _____as a child (body is in proportion)

Acromegaly

Hypersecretion of _____as an adult

Addison's Disease

Hyposecretion of _____

Cushing's Disease

Hypersecretion of _____

Chapter 16: Endocrine System, Continued

Review of the Endocrine System Glands, Hormones, & Actions

(No answers provided here—but there are answers online)

_____1. When a baby suckles the nipples of his mother this hormone is released.
_____ What gland makes this hormone?

_____2. This hormone causes water retention by the kidneys.
_____ Where is this hormone made? What gland secretes this hormone?

_____3. This hormone is secreted when blood sugar levels (glucose) are high.
_____ What gland makes this hormone?

_____4. When calcium levels in the blood are too high this hormone is released.
_____ What gland makes this hormone?

_____5. When blood sugar levels are too low, this hormone is released.
_____ What gland makes this hormone?

_____6. Calcium levels in the blood are too low, this hormone is released.
_____ What gland makes this hormone?

_____7. When the blood pressure is too low, this hormone is released.
_____ What gland makes this hormone?

_____8. The "fight-or-flight" hormones.
_____ What glands release these hormones?

_____9. This hormone is necessary for the "milk reflex."
_____ Where is this hormone made? What gland secretes this hormone?

_____10. Adrenal cortex hormone involved in regulating salt levels of fluids.
_____ Which *zona* makes this hormone?

_____11. Helps to protect the body during long-term stressful situations.
_____ What gland makes this hormone?

_____12. Hormone that programs T lymphocytes (white blood cells).
_____ What gland makes this hormone?

_____13. Basic metabolic hormone.
_____ What gland makes this hormone?

_____14. Acts with epinephrine to cause increased heart rate, breathing rate.
_____ What gland makes this hormone?

_____15. May be involved in regulating the sleep cycle.
_____ What gland makes this hormone?

_____16. Causes lengthening of the skeletal muscles during childhood.
_____ What gland makes this hormone?

Chapter 16: Endocrine System, Continued

Review of the Endocrine System Glands, Hormones, & Actions

(No answers provided here; use notes or books to find answers—or come see me for help!)

1. Describe 2-3 differences between endocrine and exocrine glands.

2. How is a negative feedback system like a furnace? Describe a negative feedback system using an example from the endocrine system.

3. What is the job of a releasing hormone? What is the job of an inhibiting hormone?

4. List the hormones produced in the anterior pituitary gland.

5. List the hormones released from the posterior pituitary gland. Where are these hormones synthesized?

6. Describe the (anatomy) structure of the adrenal cortex.

7. Compare the cause and symptoms of Addison's disease with Cushing's disease.

8. Steve runs on fast food (high in salt) and works a high stress job. Which hormones respond to his lifestyle?

9. Grandpa takes medication that lowers his blood pressure. Which hormone(s) are affected?

10. Sabrina is breastfeeding her newborn. Describe the hormone that helps to put enough calcium into her breast milk.

11. Testosterone is a steroid hormone. Describe the mechanism by which it works.

12. Gary has a pituitary gland tumor. List all of the hormones and glands that are affected.

13. Describe the relationship between the hypothalamus and the pituitary gland.

14. What hormone(s) in the blood correct a problem with low potassium?

15. Meg was alarmed to learn she has testosterone in her blood. Which gland secretes it?

16. Describe the relationship between T_3 and T_4.

17. High levels of TRH cause _____ levels of TSH and _____ levels of TH

18. Compare and contrast acromegaly and giantism.

19. What gland(s) are affected if there are low levels of ACTH in the blood?

20. In what way are the posterior pituitary and adrenal medulla similar?

Chapter 16: Endocrine System, Continued

Review of the Endocrine System

_____1. The reabsorption of sodium is regulated by:
A. adrenaline
B. insulin
C. aldosterone
D. oxytocin
E. cortisol

_____2. Which hormones regulate calcium levels?
A. insulin and glucagon
B. oxytocin and prolactin
C. adrenaline and noradrenaline
D. parathyroid and calcitonin
E. estrogen and progesterone

_____3. Direct gene activation causes:
A. proteins to be made
B. mitosis to occur
C. enzymes to activate
D. transcription & translation to occur
E. both A and D are correct

_____4. Which of these hormones is released in response to CRH?
A. oxytocin
B. ACTH
C. TSH
D. FSH
E. prolactin

_____5. If levels of growth hormone are too low, which hormone is stimulated?
A. TSH
B. GHRH
C. ACTH
D. GHIH
E. PTH

_____6. Which of these glands regulates itself through humoral control?
A. parathyroid gland
B. thyroid gland
C. pancreas
D. ovaries
E. testes

_____7. Steroid hormones are made from:
A. amines
B. proteins
C. cholesterol
D. glucose
E. glycogen

_____8. ADH promotes:
A. ovulation
B. uterine contractions
C. water retention
D. calcium reabsorption
E. growth of long bones and muscles

_____9. Water soluble hormones:
A. are made from cholesterol
B. move across a plasma membrane
C. act by direct gene activation
D. utilize the secondary messenger system
E. activate target cells to produce proteins

_____10. Thyroid hormone:
A. uses secondary messenger systems
B. behaves like lipid-soluble hormones
C. activates cAMP
D. is made from cholesterol
E. both B and D are correct

Answers: 1C, 2D, 3E, 4B, 5B, 6A and C, 7C, 8C, 9D, 10B

Chapter 19: Blood

PHYSICAL CHARACTERISTICS AND PROPERTIES OF BLOOD

- Blood is the only liquid/fluid connective tissue.
- The liquid or fluid portion of blood is the plasma . . . the *non-living matrix*.
- The solid components of blood are the *formed elements*; they include the RBC, WBC, and platelets.
- The average human *male* body contains about ____ - _____ liters (quarts) of blood. *Female*: _____ - _____, but the average *human* has around _____L of blood.
- The *pH* of blood is slightly basic and found within a narrow range, from _____ to _____.
- The *temperature* of blood is higher than body temperature at _____ degrees F.
- *Color*: oxygen-rich blood is bright, scarlet red; oxygen-poor blood is dark red or more blue.

BLOOD FUNCTIONS

1. **Transportation** (distribution) of:
   a. **Blood gases** such as oxygen from lungs to cells and carbon dioxide from cells to lungs to be exhaled
   b. **Waste products** from cells to the kidneys to be disposed
   c. **Nutrients** from GI tract to cells
   d. **Hormones** from endocrine glands to target cells.
2. **Regulation** of:
   a. **Body temperature** (high specific heat of water, skin capillaries)
   b. **pH** (7.35 to 7.45)
   c. **Water** content of the cells (regulated by ions and proteins in the blood)
3. **Protection** against:
   a. **Fluid loss** (clotting mechanism)
   b. **Foreign invaders** (leukocytes)

COMPONENTS OF BLOOD (PLASMA AND FORMED ELEMENTS)

1. **Nonliving Matrix = Plasma … makes up the majority of the blood (46-63% or average of 55%)**
   a. Clear, straw-colored liquid (matrix) portion of the blood.
   b. 90% of plasma is water (acts as a solvent and absorbs heat).
   c. Plasma carries most of the molecules needed by the cells (e.g. glucose, amino acids, hormones, enzymes, vitamins, some dissolved gases, nitrogenous wastes).
   d. There are over 100 different solutes carried in the plasma--making up 8% of plasma. The most abundant group of solutes are a group of **plasma proteins** responsible for blood osmotic pressure (BOP) made by the liver:
      1. _____ are a *main contributor* of blood osmotic pressure and a blood pH buffer; made by the liver.
      2. **Globulins** are proteins such as antibodies and thyroglobulin
      3. **Clotting proteins** such as fibrinogen

Chapter 19: Blood, Continued

COMPONENTS OF BLOOD (PLASMA AND FORMED ELEMENTS)

2. **Living Formed Elements … makes up 45% of the blood.** These are the solids components of blood made of three types of cells. Ranked from most common to least common, they are:

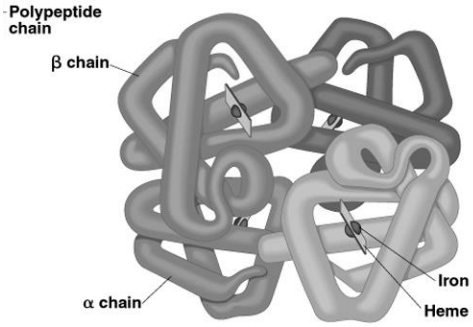
(1) Red blood cells (erythrocytes/RBC) – *most common*

(2) Platelets (cell fragments called thrombocytes)

(3) White blood cells (leukocytes/WBC) – *least common*

a. **Erythrocytes (Red blood cells = RBCs)**

- **Function**: transport oxygen and carbon dioxide. RBCs utilize glycolysis to make ATP (so they don't consume their oxygen supply during transport).
- **Anatomy:** RBCs are shaped like a biconcave disk. RBCs lack a nucleus and most organelles when mature.
- **Hematocrit** (**Ht** or **HCT**) is the proportion of blood volume that is occupied by red blood cells. It is normally about 48% for men and 38% for women. (*Why the difference?*). On average, hematocrit is about 45% .
- RBCs contain an iron-rich molecule called **hemoglobin** which binds to oxygen
  - **Hemoglobin (Hb) structure**
    - Two proteins, **globin** and **heme**, compose hemoglobin (*but*, there's 4 polypeptide chains in total)
      - **Globin** is made of two alpha (α) and two beta (β) polypeptide chains (these are proteins!)
      - Each globin is bound to a ring-like **heme** which has an iron atom in the center. (So there are four polypeptides of globin and thus, four hemes in one hemoglobin molecule).
  - **Hemoglobin function**
    - Hemoglobin transports both OXYGEN and CARBON DIOXIDE
      - **OXYGEN**: Iron can combine reversibly with one molecule of O_2…since there are four atoms of iron, each hemoglobin molecule can bind with _____ molecules of oxygen (O_2). One RBC has around 250 million hemoglobin molecules, so each of these RBC can transport 1 billion molecules of oxygen.
        - When **oxygen binds to iron**, it becomes ruby red and **oxyhemoglobin** is formed.
        - When **oxygen detaches from iron**, it becomes dark red and **deoxyhemoglobin** is formed.
      - **CARBON DIOXIDE**: About 20% of **carbon dioxide** transported in the blood binds with hemoglobin but it binds with the globin's **amino acids** rather than to the heme group.



Chapter 19: Blood, Continued

COMPONENTS OF BLOOD (PLASMA AND FORMED ELEMENTS)

2. **Living Formed Elements, continued**

a. **Erythrocytes (Red Blood Cells = RBC) … continued**

- **Normal RBC count in blood**: 4 to 6 million cells per mm^3 (cubic millimeter) of blood
- **Life span for RBC**: approximately 120 days
  - RBC cannot make new proteins, grow, or undergo mitosis.
  - After 100 to 120 days, they become trapped in the spleen (or liver) and engulfed (eaten) by macrophages. *So, what happens to the heme, globin, and iron of the hemoglobin molecule?*
    - Iron is recycled and reused to make new RBCs
    - Heme is degraded to bilirubin, a yellow-green pigment found in bile
    - Globin is broken down into amino acids (globin is a protein)

- **Hematopoiesis (Blood Cell Formation)**
  - Occurs in the red marrow of the axial skeleton bones, girdles, and in the proximal epiphyses of the humerus and femur. A stem cell known as a **hemocytoblast** gives rise to <u>all</u> formed elements.
- **Erythropoiesis** is a specific type of hematopoiesis. It's the production of red blood cells.
  - The hormone, **erythropoietin (EPO),** controls production.
  - **Stimulus**: Low oxygen stimulates the kidney cells to increases the rate of release of EPO. Low oxygen may occur due to anemia or respiratory disease, etc.
  - **Effector:** Red bone marrow makes more RBCs for release into the blood (about 3-7 days to make RBCs)
  - *KEY:* It's not the number of RBC in the blood stream that controls the rate of erythropoiesis. It's the *ability of those RBC to transport enough oxygen* to meet demands.
  - **We need these dietary requirements to make a RBC:**
    - _____
    - Vitamin _____ (comes from meat/dairy products; need intrinsic factor released by the stomach for absorption in the small intestine)
    - Folic acid (another B vitamin)
  - **To make a RBC**, the process begins in red bone marrow. It takes 3-7 days to produce an RBC:
    - **H**emocytoblast (stem cell that gives rise to <u>all</u> blood cell types)
    - **R**eticulocyte (young, anucleate erythrocyte that enters the blood stream to start oxygen transport)
    - **E**rythrocyte
  - Reticulocyte counts provide an idea of the rate of RBC formation since new ones give an idea of the up and coming RBC population

Chapter 19: Blood, Continued

COMPONENTS OF BLOOD (PLASMA AND FORMED ELEMENTS)

2. **Living Formed Elements, continued**

b. **Leukocytes (White Blood Cells = WBC)**

- **Function**: fight infection, form antibodies
- **Anatomy:** WBC possess a nucleus and most organelles; some have granules
- WBC can travel in and out of the bloodstream (*why?*); called "**diapedesis**"
- **Normal WBC count** in blood: 6,000 to 9,000 per mm^3 of blood
- **Life span for WBC** varies but typically a few hours to a few days

Granulocytes visible granules, spherical shaped cell, larger than RBC life span shorter than RBC, nuclei are lobe-shaped, function as phagocytes		**Agranulocytes** no visible granules in the cytoplasm; have spherical or kidney-shaped nuclei and are larger than red blood cells	
Type	**Function**	**Type**	**Function**
Neutrophils	Most numerous **Function:** phagocytes of bacteria and dead cells	**Lymphocytes** T lymphocytes (T cells) B lymphocytes (B cells)	**Function** in the immune response by forming antibodies
Eosinophils	**Function**: fight allergies and parasitic worms (tapeworms, pin worms, hook worms)	**Monocytes**	**Function**: phagocytes; start the immune response
Basophils	Rarest WBC **Function**: release histamine (inflammatory chemical). Histamine is a vasodilator.	Order of WBC from most common to least common: Never Neutrophils Let Lymphocytes Monkeys Monocytes Eat Eosinophils Bananas Basophils	

3. **Thrombocytes (Platelets)**

- **Function**: Clot blood during hemostasis to prevent blood loss.
- **Structure**: Platelets are anucleate cell fragments formed from the rupture of a large, multinucleated cell known as a **megakaryocytes** Megakaryocytes are produced in the bone marrow from stem cells known as hemocytoblasts.
- **Normal platelet count in blood**: _____
- **Life span for platelets**: about _____ days since they're anucleate and age quickly without repair

Chapter 19: Blood, Continued

BLOOD DISORDERS

A. **RBC Blood Disorders**

1. **Anemia**: any decrease in the blood's ability to carry oxygen.

   Results from: insufficient number of RBC or low/abnormal hemoglobin.

   Symptoms: fatigue, pale, fever, pain, achy joints

   Types of Anemia:

   - **Iron-deficiency Anemia** is a type of anemia resulting from low hemoglobin count (low iron). It is also the most prevalent type of anemia in the world. It is caused by inadequate absorption or excessive loss of iron. Occurs in females, young children, and elderly. Treatment = iron supplements.
   - **Sickle Cell Anemia** (SCA) is an inherited anemia (it's recessive). Abnormally-shaped hemoglobin becomes spiky and sharp in appearance when the RBC's unload oxygen or when oxygen content in the blood is low.
   - **Pernicious Anemia** (PA) is an autoimmune disease which is due to malabsorption of Vitamin B_{12}. Intrinsic factor, produced by the stomach mucosa, must be present for B_{12} to be absorbed by intestinal cells. Often, with pernicious anemia, intrinsic factor is deficient. (PA is a type of megaloblastic anemia)

2. **Polycythemia:** an excessive or abnormal increase in the number of RBC; technically it's a blood cancer. The increased amount of blood cells can lead to increased blood viscosity. Blood pressure rises and contributes to thrombosis and hemorrhage.

   Results from:

   a. bone marrow cancer (where the RBC's are made)

   b. response to life at higher altitudes where there is less oxygen; it's necessary to have more red blood cells to carry the little amount of oxygen that does exist.

   c. blood doping (take out RBC then reinject before sporting event to give more RBC/oxygen.)

B. **WBC Blood Disorders**

1. **Leukemia**: cancerous condition of white blood cells—they are members of a single clone that have remain unspecialized. Bone marrow becomes occupied by cancerous leukocytes.

   Characterized by:

   a. uncontrolled production and accumulation of immature WBC

   b. accumulation of too many mature WBC that do not die at the end of their life span

   Associated problems: anemia (since other cells are crowded out by cancerous WBC), fever, weight loss, bone pain

2. **Leukopenia:** WBC count is too low. Can be caused by certain drugs like corticosteroids (used to suppress the immune system for organ transplants) and anticancer agents.

3. **Infectious mononucleosis**: caused by the Epstein-Barr virus. Results in excessive number of agranulocytes.

   Characterized by: tiredness and aches, sore throat, low-grade fever

4. **Leukocytosis**: Excessive WBC count. Leukocytosis can be an indicator of infection.

Chapter 19: Blood, Continued

BLOOD DISORDERS, continued

For Discussion of Formed Elements

1. How would deficient amounts of vitamin B_{12} affect RBC production?
2. A blood test shows 3 million RBC per cubic millimeter of blood. Is this a normal level?
3. How are the granulocytes different from agranulocytes?
4. A blood test shows a high level of eosinophils. What is the likely cause?
5. Explain how low oxygen in the kidneys leads to increased RBC production.
6. Why is iron significant for RBC function?

Answers: 1. Vitamin B_{12} is needed for normal DNA synthesis in rapidly dividing populations such as RBC. Could affect level of production by lowering RBC count. 2. Not a normal level (Anemia). 3. Granulocytes have granules and lobed nuclei; agranulocytes lack granules and have spherical or kidney shaped nuclei. 4. Eosinophils attack parasitic worms, so there could be a parasitic infection. 5. Low oxygen levels in the kidney increase EPO levels. EPO is a hormone that stimulates RBC production. 6. Iron is structurally part of hemoglobin. Hemoglobin is the molecule that transports oxygen on RBC.

For Discussion of Blood Disorders

1. What artificial situation does blood doping create?
2. A white blood cell count shows 60% neutrophils in the blood. Is this a normal level? If not, what does it indicate?
3. What types of anemia can result from blood loss?
4. What are the typical causes of anemia?
5. How would you diagnose leukopenia?
6. Why do you think iron-deficiency anemia is more common in females?

Answers: 1. Polycythemia (excess RBC). 2. Yes--a normal level since neutrophils make up 50-70% of the WBC. 3. Hemorrhagic and hemolytic anemia. 4. Low numbers of RBC, abnormal or deficient amounts of hemoglobin. 5. Blood cell count to see if the WBC levels are 6,000 to 9,000 WBC per cubic millimeter. Leukopenia is a low WBC count (below 6,000). 6. Menstrual cycle creates a temporary iron-deficiency anemia situation in some females.

Chapter 19: Blood, Continued

HEMOSTASIS = *The stoppage of bleeding*

1. **Vascular Spasms**

--Vascular spasms are triggered by damage to the vessel and response of platelets. They promote:

a. Anchored platelets release **serotonin** which further enhances vascular spasms (*positive feedback*)

b. Spasms constrict the vessel (*vasoconstriction*) which reduces blood loss. (*Applying pressure to a cut mimics the vascular spasm)*

2. **Platelet Plug Formation**

--Platelets are normally repelled by intact endothelium lining blood vessels. When endothelium is broken, the platelets become "sticky." Platelets cling to the damaged site of collagen fibers. Anchored platelets release serotonin to attract more and more platelets to the site – *positive feedback*.

a. The platelets form a temporary but effective plug in sealing small blood vessel tears.

b. Aspirin inhibits the action of platelets.

3. **Coagulation/Blood Clotting**

--The chain of events that changes the blood from liquid to gel are:

a. Prothrombin activator is formed.

b. Prothrombin activator converts a plasma protein called **prothrombin** into **thrombin** (an enzyme).

c. **Thrombin** (the enzyme) catalyzes the union of **fibrinogen** molecules to create a **fibrin** mesh. The mesh traps blood cells and seals the hole until the blood vessel can be repaired.

d. The term "**clot**" = the combination of platelets and fibrin.

What items are needed to enhance clotting?

1. Vitamin _____ is needed to make some of the clotting factors
2. _____ ions are needed as a cofactor for some proteins

Clot Retraction and Repair

Within 3 to 5 minutes, the clot is stabilized and the platelets contract. As they do, they pull on the surrounding fibrin strands. The edges of the ruptured blood vessel are pulled closely together.

Fibrinolysis – why is it necessary?

A clot is not a permanent solution…so we need to remove unneeded clots once the blood vessel lining (endothelium) has healed. This process begins within two days and continues until the clot is dissolved.

What is a **thrombus**? _____

What is an **embolus** (embolism)? _____

How are thrombi and embolisms related to fibrinolysis? _____

Factors Limiting Normal Clot Growth

Anticoagulants = factors that inhibit clotting such as *heparin* (produced by basophils; also called *anti-thrombin*). Aspirin, heparin, and warfarin (Coumadin) are used to prevent undesirable clotting (*these medicines don't technically "thin" the blood; instead, the medicine inhibits clotting*)

Chapter 19: Blood, Continued

HUMAN BLOOD TYPES

Blood types are based on 3 alleles: A, B, O (A and B are *dominant* while O is recessive). We inherit some combination of two of those alleles (such as a genotype of AA, AB, OO, BO, etc.) resulting in four phenotypes: A, AB, O, B

Terms to understand:

- **Antigens (Agglutinogens or *Anti*body *Gen*erator):** molecule (such as a protein, virus, bacterium) that is recognized by the immune system and can perceived as foreign to the immune system. We have **self-antigens** that our bodies recognize as our own. It's the **non-self antigens** that trigger the immune system to create antibodies.
- **Antibodies (Immunoglobulins or Agglutinins):** formed by lymphocytes to fight specific antigens. Antibodies bind foreign antigens – a process called agglutination.
- *Do you automatically have antibodies present in your body to fight antigens?* Some antibodies, known as *immunoglobulin G* and *M (IgG and IgM)* are naturally occurring. Antibodies for the A and B antigens are found in the blood if the person lacks those antigens. So, a person with O blood has naturally occurring antibodies for A and B antigens. Upon the first transfusion containing those antigens, antibodies will clump and agglutinate the foreign blood.

<u>There are four blood types:</u> <u>A, B, AB, O</u>

- ABO Blood Groups are based on **2 antigens** found on RBC: _____
- If you have no antigens you have type _____(*most common type*)
- If you have both antigens A & B, you have type _____(*least common type*)
- If you have the A antigen, you have type _____
- If you have the B antigen, you have type _____
- Which type is the *universal donor*, being able to donate to any blood type in a transfusion?_____
- Which type is the *universal recipient*, being able to accept blood from any other person?_____

(Universal donor and recipient are no longer used as terms to describe AB and O…do you know why?)

<u>The "Rules" for Blood Typing</u>

1. The **antigens** for the ABO groups are only A or B (antigens are proteins on RBC that cause antibodies to be formed by WBC). If one has the **antigen** for the Rh (D) factor, that blood is called Rh positive.
2. Antigens (such as Rh+, A, and B) can provoke the formation or mobilization of **antibodies** (proteins formed by WBC that attack the antigens). Viruses, bacteria, and other items can present as antigens, too!
    a. We develop antibodies against A and B antigens early in life.
    b. We only develop antibodies again the Rh antigen upon exposure through transfusion (or pregnancy).
3. Rh+ blood can get Rh- blood…but Rh- cannot get Rh+.
4. Antibodies attack antigens – so antibodies are only present or created for A, B, and + antigens.
5. You cannot receive blood that contains an antigen against which you have built (or may build) an antibody. In emergency, any blood type may be given to save a life. Immunosuppressant drugs can suppress antibody formation.

Chapter 19: Blood, Continued

Rh Antigen

1. The naming of the *Rh* antigen comes from *Rh*esus monkey, the animal in which this protein was identified.
2. Most Americans (85%) are Rh+ meaning they carry the Rh antigen.

- Rh+ (Rh positive) means you have the Rh antigen on your RBC; known as having the Rh antigen.
- Rh- (Rh negative) means you do not have the Rh antigen on your RBC; do not have the Rh antigen.

3. Anti-Rh antibodies are not automatically formed and found in the blood of Rh- people. However, upon exposure (through transfusion or pregnancy) to the Rh antigen, a person will form anti-Rh antibodies.

4. **Pregnancy, Transfusions, and Rh**: The problem occurs in mothers who are Rh- and are carrying babies that are Rh+ ONLY.

First Pregnancy or Transfusion: is usually OK (because the mother doesn't have the antibodies yet!). The mother is sensitized by Rh+ antigens that pass from the placenta to her bloodstream. Mother will form anti-Rh+ antibodies unless treated with RhoGAM at 28 weeks pregnant and shortly after giving birth. RhoGAM contains anti-Rh agglutinins. The first transfusion is OK because the person will be sensitized for the first time to the Rh antigen.

Second Pregnancy or Transfusion: If there is no treatment with RhoGAM, and the mother becomes pregnant with an Rh+ baby again, her antibodies will cross through the placenta and destroy the baby's RBC's. (This time, she has the antibodies.) Likewise, the second transfusion can cause agglutination of antibodies to the foreign blood due to the already-present anti-Rh antibodies from the first sensitization (assuming no RhoGAM).

1. This 2nd baby will be born anemic and hypoxic (low oxygen) if no RhoGAM is given.
2. Brain damage and death may result unless fetal transfusions are done before birth to provide more RBC's for oxygen transport.
3. This condition is known as **erythroblastosis fetalis** or **hemolytic disease of the newborn**.

For Discussion (Hemostasis and Blood Typing) (*no answers provided here*)

1. Describe what happens during the first transfusion of an incompatible blood type.
2. Describe the process of hemostasis.
3. Describe the difference between an antigen (agglutinogens) and an antibody (agglutinins).
4. What role do the vascular spasms play in hemostasis?
5. Why is fibrinolysis necessary?
6. What role does fibrin play in hemostasis?
7. When would a RhoGAM shot be administered?

Chapter 19: Blood, Continued

ABO and Rh BLOOD GROUPS

Blood Type	**Draw the RBC showing antigens**	**Antigens**	**Antibodies**	**RECEIVE** (cannot receive blood against which antibodies may be built)	**GIVES TO** (cannot give blood to someone who hasn't seen your antigens)
A+					
A-					
B+					
B-					
AB+					
AB-					
O+					
O-					

Chapter 19: Blood, Continued

HUMAN BLOOD TYPING PRACTICE PROBLEMS

1. What blood types can you receive if you're A+? _____
2. If you have the antigen for B, what is your blood type? _____
3. If you are B-, what blood types can you receive? And give? _____
4. If you are AB+, what blood types can you receive? And give? _____
5. If you are B+, what antigens do you have? _____
6. What blood type are you if you have no antigens? _____
7. If you are A-, what blood types can you receive? And give? _____
8. If you are O+, what blood types can you receive? And give? _____
9. What blood type is considered the universal donor? _____
10. What blood type is considered the universal recipient? _____
11. What blood type has antigens for A, B, and the Rh factor? _____
12. What blood type has the antigens for the Rh factor only? _____
13. What antigens does blood type O- have? _____
14. What antigens does blood type AB- have? _____
15. If you have built antibodies for A and B, what is your blood type? _____
16. If you have built antibodies for the Rh factor only, what is your blood type? _____
17. If you have built antibodies for B only, what is your blood type? _____
18. If you are AB-, what antibodies would you form if given O+ blood? _____
19. If you are O+, what antibodies would you form if given AB+ blood? _____
20. If you are A-, what antibodies would you form if given B+ blood? _____
21. If you are A+, what antigens do you have? _____
22. What is your blood type if you have antibodies against A antigen? _____
23. What is your blood type if you have the antigens for B and the Rh factor? _____
24. What is your blood type if you have no antibodies? _____
25. What blood types can you receive if you're B+? _____
26. If you have the antigen for A and the Rh factor, what is your blood type? _____
27. If you are AB-, what blood types can you receive? And give? _____
28. If you are O+, what blood types can you receive? And give? _____
29. If you are A+, what antigens do you have? _____
30. What blood type are you if you have the A, B, and Rh antigens? _____
31. If you are B-, what blood types can you receive? And give? _____
32. If you are O-, what blood types can you receive? And give? _____
33. What antibodies does the universal donor carry? _____
34. What antigens does the universal recipient have? _____
35. What blood type has the B and Rh antigens? _____
36. What blood type has only the Rh antigen? _____
37. What antigens does blood type O+ have? _____
38. What antibodies does blood type AB+ carry? _____
39. If you have built antibodies for A and the Rh factor, what is your blood type? _____
40. If you have built antibodies for the B antigen and Rh factor, what is your blood type? _____
41. If you have built antibodies for the A antigen only, what is your blood type? _____
42. If you are AB+, what antibodies would you form if given O+ blood? _____
43. If you are A+, what antibodies would you form if given AB+ blood? _____
44. If you are B-, what antibodies would you form if given B+ blood? _____
45. If you are AB-, what antibodies would you form if given O- blood? _____
46. What is your blood type if you have antibodies against B antigen? _____
47. Who can receive your blood if your blood type is A+? _____
48. Who can receive your blood if your blood type if B-? _____
49. Who can you donate blood to if you are type AB+? _____
50. Who can you donate blood to if you are type O-? _____

Answers will be in D2L News.

Chapter 19: Blood, Continued

Review of Blood Cell Types

Identify these descriptions as leukocytes, erythrocytes, platelets, *or* plasma.

_____1. contains hemoglobin

_____2. fights infections, parasitic worms, viruses

_____3. alternate name for red blood cells

_____4. formed from the rupture of a larger cell called a megakaryocyte

_____5. carries oxygen and sometimes carbon dioxide

_____6. alternate name for white blood cells

_____7. classified as granulocytes or agranulocytes

_____8. cling together to form blood clots

_____9. subtypes include eosinophils and basophils

_____10. typically shaped like a donut with a concave center and no nucleus

_____11. the liquid, nonliving matrix of blood

Answers: 1. RBC, 2. WBC, 3. Erythrocytes, 4. Platelets, 5. RBC, 6. Leukocytes, 7. WBC, 8. Platelets, 9. Granulocytes, 10. RBC, 11. Plasma

Review of Human Blood Types: A, B, AB, O

Identify each of these descriptions or questions on blood typing.

_____1. The universal blood donor.

_____2. Anyone can receive this blood type.

_____3. The universal blood recipient.

_____4. What's your blood type if you have the antigen for A?

_____5. What's your blood type if you have the antigen for A, B, and +?

_____6. What's your blood type if you have no antigens on your RBC?

_____7. What blood type(s) can you receive if you are A+?

_____8. What blood type(s) can you receive if you're O-?

_____9. What blood type(s) can you receive if you're AB+?

_____10. What's your blood type if you only have the antigen for B?

_____11. What's your blood type if you can only receive O- in a transfusion?

_____12. What's your blood type if you can receive A-, B-, AB-, O- in a transfusion?

_____13. What blood type(s) can you receive if you are A-?

_____14. What blood type(s) can you receive if you are B+?

Answers: 1. O-, 2. O-, 3. AB+, 4. A-, 5. AB+, 6. O-, 7. A+, A-, O+, O-, 8. O-, 9. A+, A-, B+, B- AB+, AB-, O+, O-, 10. B-, 11. O-, 12. AB-, 13. A-, O-, 14. B+, B-, O+, O-

Chapter 19: Blood, Continued

Review of Blood

_____1. The most common white blood cell is:
A. basophils
B. monocytes
C. neutrophils
D. lymphocytes
E. eosinophils

_____2. Gary has blood type A+. Which type should NOT be given to him in a transfusion?
A. O+
B. AB+
C. O-
D. A+
E. A-

_____3. Serotonin ultimately causes:
A. vasoconstriction
B. a platelet plug to form
C. fibrinolysis
D. coagulation
E. vasodilation

_____4. Marquita is O-. Which pregnancy could cause her body to build antibodies against the baby's blood?
A. A-
B. B+
C. AB-
D. O-
E. B-

_____5. Which of these blood types contains NO antigens?
A. AB+
B. A-
C. B+
D. O-
E. O+

_____6. Hemoglobin has sites for _____ oxygen molecules to bind.
A. 1
B. 2
C. 4
D. 6
E. infinite

Answers: 1C, 2B, 3A, 4B, 5D, 6C

Chapter 17: Cardiovascular System: The Heart

FUNCTIONS OF THE CARDIOVASCULAR SYSTEM

1. Pump blood (heart)
2. Transport blood and items in blood (vessels)

HEART ANATOMY

Size, Shape, Orientation, and Location

- **Size:** Our hearts are about the size of a human fist. A heart weighs less than a pound.
- **Shape and Orientation**: The **apex** points toward left hip the **base** is oriented toward the right shoulder. The **point of maximum intensity** occurs between the 5^{th} and 6^{th} ribs, just below the left nipple. This is where you can feel the heart beating.
- **Location:** Located within the mediastinum in the thoracic cavity.

Coverings of the Heart

Numbered 1 – 5 are the layers and walls of the heart, from superficial to deep.

- ① **Fibrous pericardium** is the most superficial layer around the heart; it's a tough outer layer.
- **Serous pericardium** is deep to the fibrous pericardium and the parietal layer is attached to it. It is composed of two layers of serous membrane.
  - ② **Parietal pericardium**: this serous membrane is the outermost of the two.
    - **Serous fluid**: found between visceral & parietal pericardium (reduces friction) in the **pericardial cavity** (pericardial sac). *Excess serous fluid (or blood or pus) compresses the heart & limits its ability to pump blood =* ***cardiac tamponade*** *("heart plug" or pericardial effusion).*
  - ③**Visceral pericardium = epicardium:** this serous membrane is found most closely associated with the heart.

3 Walls of the Heart

1. ③ **Epicardium**: outermost layer of the heart; *same as the* visceral pericardium.
2. ④ **Myocardium**: middle layer composed of cardiac muscle that contracts the heart. *Recall* the features of the myocardium – cardiac muscle cells are connected by **intercalated discs** (gap junctions). Cells are also branched.
3. ⑤ **Endocardium**: innermost layer of the heart.

- *Pericarditis* = inflammation of the pericardium
- *Endocarditis* = inflammation of the endocardium

Chapter 17: Cardiovascular System: The Heart, Continued

4 Chambers of the Heart

Four hollow internal chambers help blood flow through the heart

1. **Atria:** two superior receiving chambers. Each atrium has an auricle ("pig's ear") that increases the surface area.

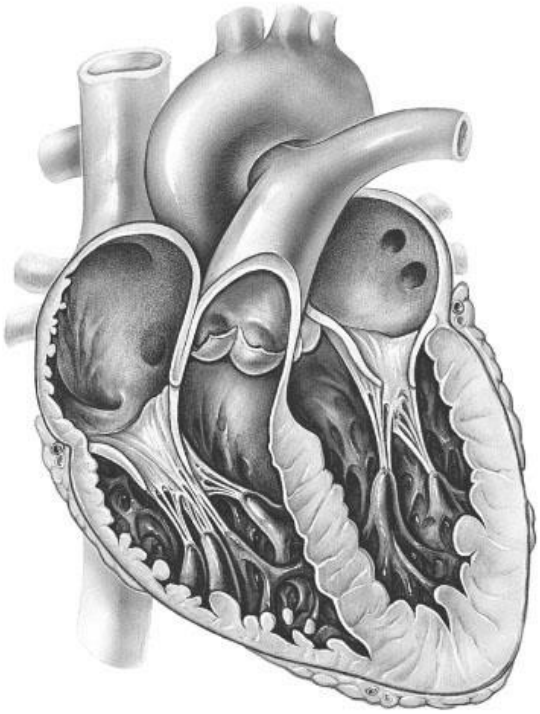
- The **right atrium** receives deoxygenated blood from these 3 **veins**
    - **Superior vena cava** (SVC) brings in blood from veins superior to the heart
    - **Inferior vena cava** (IVC) brings in blood from veins inferior to the heart
    - **Coronary sinus** brings in blood from coronary circulation
- The **left atrium** received oxygenated blood from the lungs via the 4 **pulmonary veins**.
- The atria send blood to the ventricles simultaneously.

2. **Ventricles:** two inferior discharging chambers. These chambers are more muscular than the atria.

- The right ventricle sends deoxygenated blood to the lungs when its contracts.
- The left ventricle sends oxygenated blood to the entire body via the aorta. *Do you know why the left ventricle is larger?* _____

3. **Septum** divides the heart longitudinally; it's called the **interventricular/interatrial septum.**
4. The **coronary sulcus** (groove) separates the atria from the ventricles externally. It contains blood vessels and fat.

Label the four chambers and four valves of the heart.



Chapter 17: Cardiovascular System: The Heart, Continued

4 Valves of the Heart

Four valves force blood to flow only one direction through the heart & prevent backflow of blood.

1. **Atrioventricular valves (AV)** are located between the atrial & ventricular chambers on each side.
   a. **Tricuspid valve (Right AV valve)**: between the right atrium and ventricle; has 3 flaps
   b. **Biscuspid valve** (**Left AV valve; mitral valve**): between the left atrium and ventricle; has 2 flaps

   What does each valve do? These valves shut during heart contraction to prevent blood from being pumped from each ventricle back into its associated atrium.

   --**chordae tendineae**, the "heart strings" anchor the cusps to the papillary muscles in the ventricles. They prevent the valves from being inverted into the atria.

   --when heart is relaxed and blood is passively filling its chambers, the AV valve flaps hang **open** limply in the ventricles.

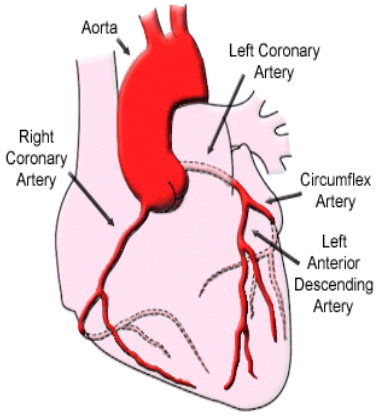
   --when the ventricles contract, the pressure rises inside the heart rises; the AV valves are forced upward, the valves **close**.
2. **Semilunar valves (SLV)** guard the bases of 2 large arteries leaving the heart: aorta & pulmonary trunk
   a. **Pulmonary semilunar valve** guards the base of the pulmonary trunk—an artery heading to the lungs.
   b. **Aortic semilunar valve** guards the base of the aorta—an artery leading to the body.

   --these semilunar valves are **closed** during heart relaxation and **open** when the ventricles contract.

CORONARY CIRCULATION

Blood that nourishes the myocardium comes from blood vessels known as **coronary arteries** that branch from the aorta. The myocardium is too thick to receive oxygen or nutrients by diffusion.

- The 2 main **coronary arteries**, the right and left coronary artery, branch from the base of the **aorta** and encircle the heart in the atrioventricular groove at the junction of the atria and ventricles.
- The coronary arteries and major branches are compressed when the ventricles are contracting and fill when the heart is relaxed. The coronary arteries supply oxygenated blood to the myocardium.
- Cardiac veins join together to form a large vessel called the coronary sinus.
- The myocardium is drained by the **coronary sinus** which returns deoxygenated blood to the R atrium.

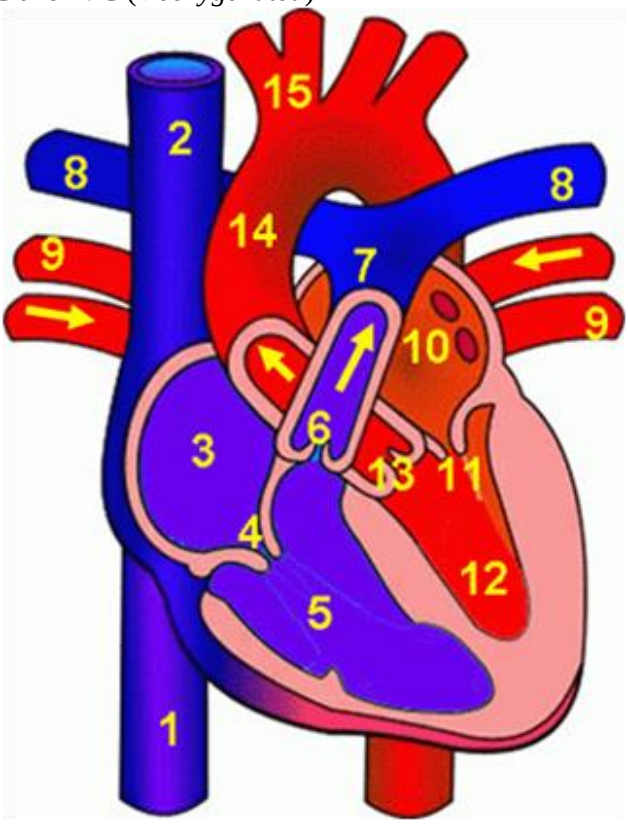


Chapter 17: Cardiovascular System: The Heart, Continued

PATHWAY OF BLOOD

(Systemic and Pulmonary Circulation Included)
(When listing the flow on the test, you do not have to indicate if the blood is oxy- or deoxygenated)
Be prepared to start anywhere in this flow path.

- Superior Vena Cava (SVC), Inferior Vena Cava (IVC), Coronary Sinus (CS) (*Deoxygenated*)
- Right (R) Atrium (*Deoxygenated*)
- Tricuspid Valve (*Deoxygenated*)
- Right Ventricle (*Deoxygenated*)
- Pulmonary Semilunar Valve (SLV) (*Deoxygenated*)
- Pulmonary Trunk (*Deoxygenated*)
- Pulmonary Arteries (*going to the lungs to pick up oxygen, drop of carbon dioxide)*
- Pulmonary Arterioles
- Pulmonary Capillaries surround alveoli of lungs (*Gas Exchange*)
- Pulmonary Venules
- Pulmonary Veins (*returning to the heart with oxygenated blood)*
- Left (L) Atrium (*Oxygenated*)
- Bicuspid Valve (*Oxygenated*)
- Left Ventricle (*Oxygenated*)
- Aortic Semilunar Valve (*Oxygenated*)
- Aorta (*Oxygenated*)
- Arteries of the body (*Oxygenated*)
- Arterioles (*Oxygenated*)
- Capillaries (*Gas Exchange*)
- Venules (*Deoxygenated*)
- Veins (*Deoxygenated*)
- Return to the heart via the SVC and IVC (*Deoxygenated*)



Chapter 17: Cardiovascular System: The Heart, Continued

CARDIAC CONDUCTION SYSTEM

Cardiac Muscle Tissue

Cardiac muscle cells consist of **separate, small fibers**. Cells contain **intercalated discs** (gap junctions). Impulses can travel directly from cell to cell. **Branched cells** allow messages to spread to heart muscle for simultaneous contraction.

How Heart Rate is Controlled

Cardiac muscle cells contract spontaneously and independently of nerve stimulation. Contractions occur in a regular and continuous way (atria, then ventricles). Muscle cells in different areas of the heart beat in different rhythms. So, the heart needs a controlling system to regulate heart activity . . .

Intrinsic Conduction System/Nodal System is built into the heart tissue. This system initiates impulses in the heart using **autorhythmic cells** that spontaneously and independently send impulses telling the heart to contract. The normal heart rate is _____ **beats per minute** at rest (the normal range is _____ to _____ beats per minute).

- **Tachycardia** – abnormally fast heart rate above _____ beats per minute. May result from elevated body temperature, stress, certain drugs, heart disease. Treated with digitalis, pilocarpine, beta blockers, alpha blockers.
- **Bradycardia** – heart rate slower than _____ beats per minute. May result from low body temperature, certain drugs, parasympathetic nervous action. Treated with atropine, pacemaker, thyroid medication.

Intrinsic Conduction System Pathway

① **Sinoatrial node** (SA node) is a node of built-in nervous tissue located in the top of the right atrium; called the pacemaker. **SA node** starts each heartbeat and sets the pace for the whole heart; nerve impulses from this node cause…

② **Atrial contraction**. As the pacemaker's impulse spreads across the atria, it eventually reaches the…

③ **Atrioventricular (AV) node (junction)**, a mass of cells at the base of the R atrium (interatrial septum). From this **AV node**, the impulse crosses over into the ventricles and runs down the …

④ **AV bundle** (**bundle of His or junction)** (only electrical bridge between atria and ventricles) in the interventricular septum. This septum divides into right and left ventricles that carry the impulse to the walls of both ventricles. The AV bundle splits into …

⑤ **Right and left bundle branches** which terminate in many …

⑥ **Purkinje fibers**. These fibers stimulate all cells of the ventricle causing …

⑦ **Ventricular contraction**. This electrical activity of the heart's conduction system can be detected on the body's surface with electrodes. A recording of this activity is called an electrocardiogram (EKG or ECG).

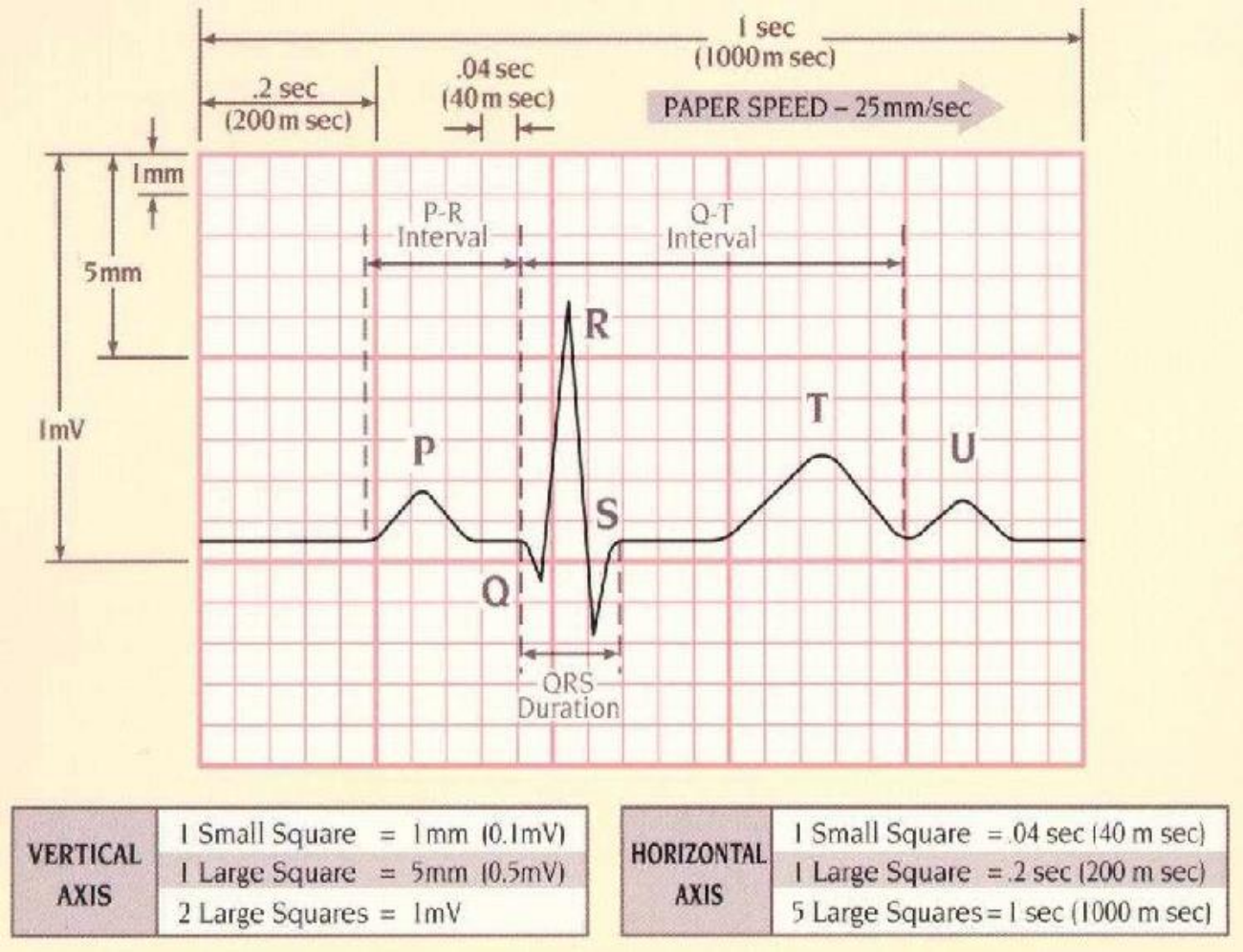
Autonomic Nervous System Override Control (*Remember Negative Feedback*?)

The ANS can override heart rate. The **cardiac center**, within the **cardiovascular center,** is situated in the medulla.

- If heart rate is too slow…the cardiac center initiates **sympathetic** nervous system control. The sympathetic NS speeds the firing of the SA node using epinephrine and NE. Heart rate will **increase**.
- If heart rate is too fast…the cardiac center initiates **parasympathetic*** nervous system control. The parasympathetic NS slows the heart rate using the vagus nerve and ACh. Heart rate will **decrease**. **dominant system*

Chapter 17: Cardiovascular System: The Heart, Continued

READING AN ELECTROCARDIOGRAM (ECG or EKG)



- **P Wave**
  - **Atrial depolarization** (*depolarization* means the atria are getting ready to contract as sodium rushes into the cardiac muscle cells)…The P wave is seen in response to the firing of the SA node.
- **QRS Wave**
  - **Ventricular depolarization** (*depolarization* means the ventricles are getting ready to contract)…QRS wave is seen in response to the firing of the AV node
  - **Atrial contraction** and **atrial repolarization** happens hidden behind the QRS wave but cannot be seen.

  Why is the QRS wave so large in comparison to the P wave? _____

  _____
- **T Wave**
  - **Ventricular repolarization** (*repolarization* means the ventricles already contracted and are returning to the resting potential).

→ **What is the length of time between heart beats?** Measure R - R wave peaks. Average time is 0.8 seconds.

→ **How do I estimate heart rate?** Estimate the number of big boxes (0.2 sec) between R-R wave peaks. Average heart rate is 75 bpm.

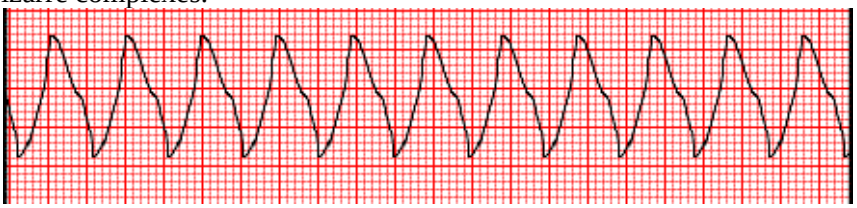
Chapter 17: Cardiovascular System: The Heart, Continued

Potentially Lethal or Fatal EKG Problems

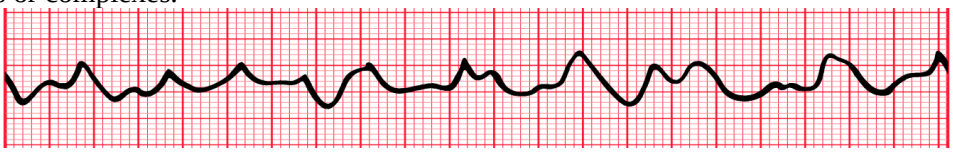
Asystole (Flatline) = all electrical activity ceases; lethal arrhythmia that is resistant to resuscitation efforts. Epinephrine is administered to see if electrical activity returns, or heart massage may be done.

Third Degree Heart Block (Complete Heart Block) = SA node impulse does not travel to the ventricles, the impulse is *blocked* because the block at the AV node is complete. No relationship between timing of P waves and QRS complexes.

Ventricular Tachycardia = SA node not in control; Life threatening and can lead to v-fib, asystole, or death. Characterized by wide, bizarre complexes.

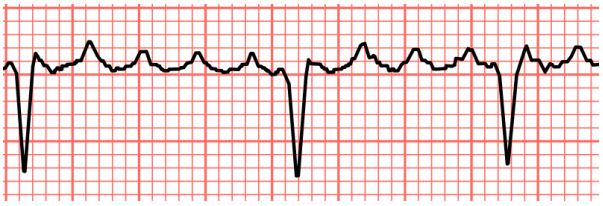


Ventricular Fibrillation (V-Fib) = uncoordinated ventricular contraction; common in cardiac arrest patients. There are no measurable waves or complexes.

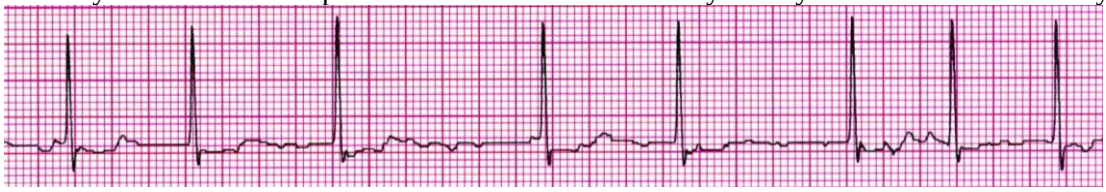


Non-Life Threatening EKG

Atrial Flutter = has a "saw tooth" appearance and can lead to atrial fibrillation. The atrial rhythm is regular if the AV node conducts impulses through in a consistent pattern. Atrial rate is 250-350 beats per minute while the ventricular rhythm is usually regular.



Atrial Fibrillation (A-Fib) = everything about this EKG is <u>irregular</u> atrial contraction (notice timing). No discernible P waves. Atrial rate may exceed 350 beats per minute and the ventricles may or may not have a controlled rhythm.



Chapter 17: Cardiovascular System: The Heart, Continued

Blood Pressure Stages

Blood Pressure Category	Systolic mm Hg (upper #)		Diastolic mm Hg (lower #)
Low blood pressure (Hypotension)	less than 80	or	less than 60
Normal	80-120	and	60-80
Prehypertension	120-139	or	80-89
High Blood Pressure (Hypertension Stage 1)	140-159	or	90-99
High Blood Pressure (Hypertension Stage 2)	160 or higher	or	100 or higher
High Blood Pressure Crisis (Seek Emergency Care)	higher than 180	or	higher than 110

Source: American Heart Association

What blood pressure numbers mean:

$$\frac{120}{80}\ \text{mm Hg}$$

Systolic pressure created by ventricular contraction (*known as* **systole**) Atrial diastole occurs during ventricular systole.

Diastolic pressure created by atrial contraction. Ventricular relaxation (*known as* **diastole**) occurs during this period of atrial systole.

CARDIAC CYCLE (0.8 second)

Mid-to-Late Ventricular Diastole (Ventricular filling)

- Blood enters the atria under **LOW** pressure
  - To the **R atrium** from the SVC, IVC, and coronary sinus
  - To the **L atrium** from the pulmonary veins
- Blood travels through the **OPEN AV** valves. Semilunar valves are **CLOSED**.
- Blood drains into the ventricles (*ventricular filling*) and pressure in the left ventricle is low (70 – 80 mm Hg)

Atrial Systole

- **SA node** fires a nerve impulse and atria contract, pushing blood into the ventricles.
- The volume of blood in each ventricle is known as the **END DIASTOLIC VOLUME (EDV) = 120 mL**

Ventricular Systole (Atrial Diastole)

- **AV node** now fires a nerve impulse and ventricles begin to contract.
- **AV valves** slam shut (LUB heart sound).
- Pause for a moment: the semilunar valves are closed and have not yet opened. For this brief moment, all 4 heart valves are closed, a time period known as **ISOVOLUMETRIC CONTRACTION PHASE**.
- Pressure in the heart in the left ventricle is high (110 – 120 mm Hg)
- So, the semilunar valves are forced to **OPEN** while the AV valves remain **CLOSED**.

Chapter 17: Cardiovascular System: The Heart, Continued

CARDIAC CYCLE, continued

- Blood is ejected from each ventricle, a volume known as **STROKE VOLUME = 70 mL**
  - From the **R ventricle**, blood travels to the pulmonary trunk
  - From the **L ventricle**, blood travels to the aorta
- Some blood remains behind, a volume known as **END SYSTOLIC VOLUME = 50 mL**
- With each heart beat, the ventricles pump out about 60% of their blood, a percentage known as the **EJECTION FRACTION** (which is about **70 mL** – stroke volume - of blood…since 70 mL/120 mL = 58.3%). Hospitals desire E_f to be between 50 and 65%.

Early Ventricular Diastole (Isovolumetric relaxation) (Atrial Systole)

- After blood leaves the heart, ventricular pressure drops, and the semilunar valves **CLOSE** to prevent blood from flowing back into the ventricles. This results in the second heart sound "dupp." DUPP is a shorter sound.
- Pause once again because all four heart valves are briefly closed, known as **ISOVOLUMETRIC RELAXATION PHASE.**
- Now, we're back to the beginning. Blood continues to enter the atria under low pressure from body, heart & lungs.

Right vs. Left Side Pressure Differences

- **Right side** pressure is ____/____ mm Hg
  - Pulmonary circuit
- **Left side** pressure is ____/____ mm Hg
  - Systemic circuit

Abnormal Heart Sounds

Heart murmurs often result from:

- **Incompetent valves =** swishing sound is heard as blood backflows due to valves that do not close properly
- **Stenotic valve** = valve opening is narrowed and restricts blood flow through it…often makes a high-pitched sound as blood tries to flow through. Stenotic valves decrease cardiac output and E_f.
- **Mitral valve prolapse** (MVP) = malfunction of papillary muscles or abnormal chordae tendineae. Blood backflows from the left ventricle through the valve into the left atrium. *Why do you think this valve is more affected than the tricuspid valve*? _____

Chapter 17: Cardiovascular System: The Heart, Continued

CARDIAC OUTPUT

Cardiac Output (CO) = the amount of blood ejected by the heart in one minute

- Normal CO averages approximately 5 L (more for a male and less for a female)

Cardiac output depends on two factors (variables):

- **Heart Rate (HR)** = number of beats per minute; on average 75 beats per minute
- **Stroke Volume (SV)** = volume of blood pumped out of the L ventricle during each contraction; 70 mL

CO = HR x SV

CO = 75 beats/min x 70 mL/beat = 5,250 mL/min = 5.25 L/min

SV represents the difference between these two volumes:

- **EDV** = volume of blood in a ventricle during diastole (about 120 mL) before contraction
  - Depends on how long ventricular diastole lasts or venous pressure
- **ESV** = volume of blood left in a ventricle after contraction (about 50 mL)
  - Depends on arterial pressure and the force of ventricular contraction

SV = EDV – ESV

SV = 120 mL/beat – 50 mL/beat = 70 mL/beat

THREE FACTORS AFFECTING STROKE VOLUME

1. **Preload** (≈ EDV which is blood traveling into each ventricle). Preload is the **stretch** experienced by each ventricle as they fill with blood prior to contracting.
   - Preload is **INCREASED** by anything that increases the volume or speed of venous return (exercise).
   - Preload is **DECREASED** by nitroglycerin, a vasodilator.
2. **Contractility** is the contractile **strength** achieved at a given muscle length.
   - Contractility is **INCREASED** by excess calcium, sympathetic stimulation, glucagon, thyroxine, or digitalis.
   - Contractility is **DECREASED** by excess potassium, drugs such as calcium channel blockers
3. **Afterload** is the **pressure** in the arteries (aorta and pulmonary trunk) leaving the heart that must be overcome for the ventricles to eject blood. It is affected by the pressure in the aorta and the lungs.

For Discussion:

1. If heart rate increases, how are stroke volume and cardiac output affected? How are preload and afterload affected?
2. Identify two possible causes for heart murmur. What is the role of the heart valves in blood flow in the heart?
3. Define *diastole* and *systole* and relate them to the activities and pressure within the ventricles.
4. Define *end diastolic volume (EDV)* and *end systolic volume (ESV)*, provide their volumes, and relate them to the calculation of stroke volume.
5. How would stroke volume be affected during exercise? Would SV increase or decrease? Why?
6. Which of the following volumes is the greatest? EDV, ESV, SV, CO

Chapter 17: Cardiovascular System: The Heart, Continued

Regulation of Heart Rate (*Recall, CO = HR x SV)*

What INCREASES heart rate (and cardiac output)?

- **Sympathetic nervous system activity** which release epinephrine and norepinephrine upon emotional or physical stressors (*fight or flight*). The sympathetic nervous system innervates *both* atria and ventricles, increasing heart rate, conduction, and irritability (ability to sense a stimulus).
- **Hormones**
  - **Epinephrine & NE**
  - **Thyroxine**
- **Ions**
  - **Hypercalcemia (high calcium levels)** may be due to hyperparathyroidism
  - **Hypokalemia (low potassium levels)** heart beats arrhythmically. *Causes of hypokalemia: aldosterone issues, Lasix (loop diuretic) & insulin (injections), diarrhea, vomiting, excessive perspiration.*
- **Fever**
- **Caffeine**

What DECREASES heart rate (and cardiac output)?

- **Parasympathetic nervous system activity** promotes the release of _____ which slows the heart after sympathetic activity. The parasympathetic nervous system, via the vagus nerve, innervates the SA node *only*, slowing heart rate, conduction, and irritability.
- **Vagal tone** is the effect of the vagus nerve on heart rate. Vagus nerve stimulation SLOWS the heart rate.
  - **Atropine** is a drug used to counteract the effects of the vagus nerve. It increases heart rate in cases of bradycardia (heart rate below 60 beats per minute).
  - **Vasovagal syncope** (common cause of fainting). BP drops due to overstimulation of the vagus nerve.
  - **Vagal (Valsalva) maneuver** can be used to slow fast heart rate and includes gagging, holding your breath, coughing, holding your face in ice cold water…and even bearing down for a bowel movement.
- **Ions**
  - **Hypocalcemia (low calcium levels)**
  - **Hyperkalemia (high potassium levels)** alters the resting potential and may cause heart block and cardiac arrest. Insulin counters the effects of excess potassium and forces potassium ions to re-enter cells.
- **Medications (**www.heart.org is a great resource) that are used to lower heart rate also treat hypertension:
  - **Beta blockers** block the action of epinephrine or norepinephrine. These drugs are used to lower heart rate, which lowers the blood pressure.
  - **Alpha blockers** relax vessels and reduce their resistance to blood flow.
  - **Calcium channel blockers** block calcium from entering muscle cells of the heart's arteries, so the vessels around the heart dilate. Heart rate and blood pressure are lowered.

Chapter 17: Cardiovascular System: The Heart, Continued

HEART DISORDERS

Cardiac Output

- **Congestive Heart Failure or Chronic Heart Fatigue (CHF)** – progressive, chronic condition resulting in heart failure.
    - **Caused by**:
        - **coronary atherosclerosis** – clog coronary vessels with fatty buildup
        - **high blood pressure** – myocardium must exert more force to expel blood; hypertrophy of myocardium
        - **multiple myocardial infarcts** (MI) – dead heart cells replaced by fibrous tissue (scar tissue)
        - **dilated cardiomyopathy** (DCM) – ventricles stretch and become flabby (cause unknown)
    - **Results in**:

This is commonly missed on tests!

        - **Left side heart failure → pulmonary congestion** The failing left side does not adequately eject blood into systemic circulation. Blood backs up and the lungs fill with blood; fluid leaks into the surrounding tissue causing **pulmonary edema** & leading to suffocation.
        - **Right side heart failure → peripheral congestion** The failing right side of the heart does not adequately eject blood into pulmonary circulation. Thus, fluids back up in the systemic venous network and fills organs and tissues -- resulting in edema in the extremities (feet, ankles, fingers).
    - **Treatment**:
        - **Diuretics** (increase excretion of sodium and water by kidneys)
        - **Blood pressure drugs** that lower BP and afterload
        - **Digitalis drugs** to reduce blood pressure to conserve heart energy
        - **Heart transplants**

For Discussion:

1. Why do you think older people are more susceptible to suffer from heart attacks in the winter time – especially while shoveling snow?
2. Why does right side CHF lead to peripheral problems while left side CHF leads to pulmonary problems?
3. How does holding one's breath (such as to push out a bowel movement) affect heart rate?
4. Insulin medications for diabetics can cause low potassium levels. How would this situation affect heart rate?

Chapter 17: Cardiovascular System: The Heart, Continued

HEART DISORDERS, continued

Myocardial infarction (MI) "Heart attack" - The result of interrupted blood supply to an area of the heart. Without O_2, the area of heart tissue dies *(infarction)*, and the heart weakens. Heart muscle cells are amitotic and don't replace themselves – instead the tissue is replaced with collagen fibers (scar tissue).

- **Caused by**: Blockage of coronary artery (thrombus - blood clot formed in coronary vessel); Embolus (blood clot formed elsewhere, but travels to heart & lodges there); or a vessel may be blocked due to accumulated fatty deposits (atherosclerosis). Atherosclerosis starts with damage to endothelial lining.
- **Diagnosis**: EKG & serum enzyme studies. Whether a person survives depends on the extent and location of the damage.
  - **Troponin** is used to diagnose a heart attack because it differentiates between angina and myocardial infarction. A patient with damaged heart muscle would have elevated levels of troponin.
  - **Creatine kinase** (CK) only indicates muscle damage-but it does not specifically indicate what type of muscle. So troponin is a more effective test for heart muscle damage than CK**.**
- **Treatment**: use of blood-pressure lowering drugs called beta-blockers and ACE inhibitors (angiotension-converting enzyme).
  - **Beta blockers** inhibit sympathetic nervous system action (epinephrine and norepinephrine) and prevent increases in blood pressure and strain on the heart
  - **ACE inhibitors** lower blood pressure (by preventing the formation of angiotension II and ultimately aldosterone) and break down kinins to improve heart function. They lower fat and sodium in blood.
- **Symptoms**: chest pain; pain in the jaw, arm, shoulder; indigestion, nausea, vomiting; clammy moist skin, sweating

Angina pectoris or "**chest pain**" - *Temporary ischemia* (reduced oxygen) to the myocardium causes myocardial cells to weaken, but not die.

- **Caused by**: coronary vessels constrict due to nicotine, atherosclerosis, and strenuous exercise after a meal, or high blood pressure.
- **Symptoms**: chest pain or tightness, and difficulty breathing (shortness of breath)

DEVELOPMENT OF THE HEART

Bypasses in the fetal heart (close at or shortly after birth)

- **Foramen ovale** – connects the atria allowing blood to pass from the right atrium to the left atrium bypassing the lungs. Becomes the **fossa ovalis** after birth, visible in the right atrium.
- **Ductus arteriosus** – connects the pulmonary trunk and aorta. Becomes the **ligamentum arteriosum** after birth.

For Discussion:

1. Name 2 shunts that bypass the lungs in a fetus. Briefly explain the structures these shunts connect.
2. Differentiate between a myocardial infarction (MI) and angina pectoris (ischemia).
3. Why is a blood test for creatine kinase perhaps not the best one to confirm a heart attack? Why type of test is better?

Chapter 17: Cardiovascular System: The Heart, Continued

Review of Heart Blood Flow, Physiology, and Blood Vessels

_____1. Through which artery does blood flow after it leaves the right ventricle?

_____2. Through which artery does blood flow after it leaves the left ventricle?

_____3. Through which veins does blood return to the heart from the body?

_____4. Which valves are closed during ventricular contraction?

_____5. Which valves are closed during systole?

_____6. Which chamber receives blood from the lungs?

_____7. What is the circulation called when blood travels to and from the lungs?

_____8. What is the circulation called when blood travels to and from the body?

_____9. Which chambers are contracting during systole?

_____10. What does diastole mean?

_____11. When the ventricles contract, which valves open?

_____12. Which valves are anchored by chordae tendineae?

_____13. Blood that enters the pulmonary semilunar valve just left the ___ chamber.

_____14. Blood that enters the aortic semilunar valve just left the ___ chamber.

_____15. Blood that begins its journey in systemic circulation leaves the heart through this artery.

_____16. Through which valve does blood pass on its way from right atrium to right ventricle?

_____17. Through which valve does blood pass after it leaves the left atrium?

_____18. The ___ valve prevents blood from back-flowing into the left ventricle.

_____19. The ___ valve prevents blood from back-flowing into the left atrium.

_____20. Which valves guard the entrances to the aorta and pulmonary arteries?

_____21. Which valves are found between the atria and ventricles?

_____22. Blood leaves the heart and travels to the lungs in these blood vessels.

_____23. Pressure is high in these chambers of the heart during systole.

_____24. Pressure is low in the heart during ___.

_____25. These valves are open during systole.

_____26. Blood enters this chamber of the heart from the SVC and IVC.

_____27. These blood vessels found all over the body have valves.

_____28. Do <u>all</u> arteries carry oxygenated blood?

_____29. Do <u>all</u> veins carry deoxygenated blood?

_____30. What types of vessels have a thicker tunica media (middle layer)?

Answers: 1. pulmonary trunk, 2. aorta, 3. SVC and IVC, 4. atrioventricular valves (tricuspid and bicuspid), 5. atrioventricular valves (tricuspid and bicuspid), 6. left atrium, 7. pulmonary circulation, 8. systemic circulation, 9. ventricles, 10. relaxation, 11. semilunar valves (pulmonary and aortic), 12. atrioventricular valves (tricuspid and bicuspid), 13. right ventricle, 14. left ventricle, 15. aorta, 16. tricuspid valve, 17. bicuspid valve, 18. aortic semilunar valve, 19. bicuspid valve, 20. semilunar valves, 21. atrioventricular valves, 22. pulmonary arteries, 23. ventricles, 24. diastole, 25. semilunar valves, 26. right atrium, 27. veins, 28. no-pulmonary arteries carry deoxygenated blood, 29. no-pulmonary veins carry oxygenated blood, 30. arteries

Chapter 17: Cardiovascular System: The Heart, Continued

Review of Parts of the Heart

Identify these parts of the heart dealing with anatomy or blood circulation through the heart/lungs.

_____1. these large veins return blood to the right atrium

_____2. these are the valves located between atria and ventricles

_____3. the chamber where blood first returns to the heart after system circulation

_____4. the layer of the pericardium that is closest to the heart

_____5. the layer of the pericardium that is away from the heart

_____6. these two chambers are the "pumping" chambers of the heart

_____7. these two chambers are under high pressure during heart contraction

_____8. these are the heart strings which anchor the AV valves

_____9. these valves are found on the pulmonary semilunar and aortic valves

_____10. the muscle of the heart is called the ___.

_____11. the ___ of the heart is found pointing toward the right shoulder

_____12. the ___ of the heart is found pointing toward the left hip

_____13. the heart is about the size of ___.

_____14. the sinoatrial node is found in this chamber

_____15. the blood returns from the lungs and enters this chamber

_____16. the chamber blood goes to after the left atrium

_____17. the large artery found leaving the heart is the ___.

Answers: 1. Superior & inferior vena cava, 2. Atriventricular valves, 3. Right atrium, 4. Visceral Pericardium, 5. Parietal Pericardium, 6. Ventricles, 7. Ventricles, 8. Chordae tendineae, 9. Semilunars, 10. Myocardium, 11. base, 12. apex, 13. Human fist, 14. Right atrium, 15. Left atrium, 16. Left ventricle, 17. Aorta

The Cardiac Cycle and Blood Pressure

_____1. diastole means the heart is (contracting/relaxed).

_____2. when the heart is contracting, the semilunar valves are (open/closed).

_____3. when the heart is relaxed, we call this:

_____4. during diastole, the blood is forced from the ___ to the ___.

_____5. systole means the heart is (contracting/relaxed).

_____6. when the heart is relaxed, the semilunar valves are (open/closed).

_____7. during systole, these chambers are filling with blood

_____8. during diastole, these chambers are expelling blood to the ventricles

Answers: 1. Relaxed, 2. Open, 3. Diastole, 4. Atria to the Ventricles, 5. Contracting, 6. Closed, 7. Atria, 8. Atria

Chapter 17: Cardiovascular System: The Heart, Continued

Review of the Heart

_____1. What is the normal cardiac output for the average person?
A. 2L
B. 4L
C. 5L
D. 8L
E. 12 L

_____2. The atrioventricular valves are open when:
A. the ventricles are contracting
B. pressure in the ventricles is high
C. the semilunar valves are closed
D. the heart is in systole
E. blood is leaving the ventricles

_____3. Which of these factors will decrease cardiac output?
A. increased stroke volume
B. epinephrine
C. thyroxine
D. hyperkalemia
E. increased heart rate

_____4. Which of these structures in a fetus allows blood to pass directly from the right to the left atrium?
A. ductus arteriosus
B. foramen ovale
C. interventricular septum
D. aortic stenosis
E. fossa ovalis

_____5. Beta blockers decrease heart rate by interfering with the activity of:
A. epinephrine
B. thyroxine
C. nitroglycerin
D. vagus nerve
E. parasympathetic nervous system

_____6. Which wave on an EKG indicates atrial depolarization?
A. P wave
B. Q wave
C. QRS complex
D. T wave
E. UV wave

Answers: 1C, 2C, 3D, 4B, 5A, 6A

Chapter 18: Cardiovascular System: Blood Vessels

GENERAL BLOOD VESSEL STRUCTURE

- **Tunica intima** – innermost layer; in "intimate" contact with blood. This layer is the endothelium (simple squamous)
- **Tunica media** – middle, bulky layer consisting of circularly arranged smooth muscle cells and sheets of elastin. The smooth muscle is under ANS control and contracts to maintain blood flow and pressure. Arteries have a thicker tunica media than veins. Capillaries *lack* the tunica media (and externa).
    - **Vasodilation** – smooth muscle relaxes and diameter inside increases
    - **Vasoconstriction** – smooth muscle contractions and diameter inside decreases
- **Tunica externa** – outermost layer composed of collagen fibers and contains nerves and lymphatics.

TYPES OF VESSELS

Arteries

- Arteries carry blood **away** from the heart! (Almost always)
- Arteries are typically **red** because they *usually* carry oxygenated blood and low amounts of CO_2. *Pulmonary arteries are the exception to this rule; they carry deoxygenated blood away from the heart to the lungs.*
- Arteries need strong and stretchy tunica media to handle the high pressured blood.
- Two types of arteries:
    - **Elastic arteries** (**conducting arteries**) – thick, contain elastin, and handle high pressure such as the aorta, pulmonary trunk, common carotid artery, and subclavian artery…branch into:
    - **Muscular arteries** (**distributing arteries**). These muscular arteries deliver blood to specific body organs and have the thickest layer of smooth muscle (such as the femoral artery, radial artery, etc.). Muscular arteries are used for taking the pulse (pressure point).
        - Your "pulse" is felt in muscular arteries, such as the radial artery. The pulse is the alternate expansion & recoil of the elastic artery walls during each cardiac cycle; this pressure wave can be felt at any artery lying close to the skin.
- Arteries feed into smaller arteries are called **arterioles** which feed into capillaries where exchanges occur.

Veins

- Veins **return** blood to the heart!
- Veins are typically **blue** because they *usually* carry high amounts of CO_2 and low amounts of O_2. *The pulmonary veins are the exceptions to this rule; they carry oxygenated blood back to the heart.*
- Three things assist with the return blood in the veins back to the heart:
    1. **Valves** – prevent the backflow of blood
        - **Varicose veins**: weak venous valves cause blood to pool in veins of the legs
    2. **Respiratory pump** (breathing) - lowers pressure in the thoracic cavity and helps return fluids to heart
    3. **Muscular pump** - compression of skeletal muscles squeezes veins
- Small veins are called _____. Venules join with capillaries to take blood back to the heart.

Chapter 18: Cardiovascular System: Blood Vessels, Continued

TYPES OF VESSELS

Capillaries

- Thin walls only composed of tunica _____.
- Narrow diameter allows cells to flow through single file
- Capillaries exist in capillary beds with sphincters that control blood flow through the bed. The bed provides a greater surface area over which exchanges can occur.
- Capillary function: capillaries allow the exchange of fluids, nutrients, wastes, hormones, solutes, with surrounding cells and tissues.
    - Capillaries with **fenestrations** (such as those in the liver, lymphatic system, and glands) allow for exchanges
    - **Closed capillaries** lack fenestrations and prevent exchanges with the interstitial space (such as the blood-brain barrier)

Summary of Systemic Circulation (to and from body)

aorta (leaving heart) → arteries → arterioles → capillaries → venules → veins → SVC and IVC → heart

Summary of Pulmonary Circulation (to and from lungs)

right ventricle of heart → pulmonary trunk → pulmonary arteries → to lungs where gas exchange occurs at capillaries surrounding alveoli → pulmonary veins → left atrium of heart

For Discussion:

1. Explain how blood flow into a capillary can be controlled.
2. What types of vessels contain valves? Why are valves found in those vessels?
3. How does the structure of a capillary different from both artery and vein structure?
4. Why do models show the pulmonary artery and vein colored opposite from nearly all systemic vessel colorings?

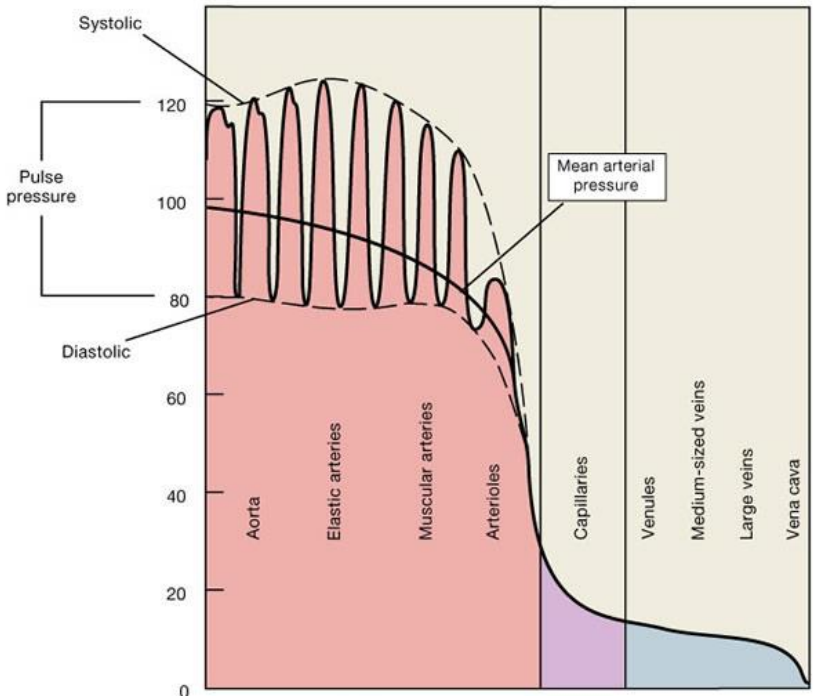
PHYSIOLOGY OF CIRCULATION

- **Blood Pressure (BP)** – the pressure the blood exerts against the inner walls of the blood vessels and the force that keeps blood circulating continuously between heartbeats (mm Hg.)
    - Blood flows through its system of closed vessels because of differences in pressure. Blood always flow from areas of HIGH BP to areas of LOW BP.
    - BP = pressure within large systemic arteries around the heart (known as systemic arterial BP).
        - What vessel experiences the **highest** BP? _____
        - Which vessels experience the **steepest drop** in BP due to an increase in PR? _____
        - BP is *higher* when it enters the capillary beds (35 mm Hg) and *lower* when it leaves (15 – 17 mm Hg)
        - BP continues to drop as it flows through the venules and veins, finally reaching 0mm Hg in the R atrium.

Chapter 18: Cardiovascular System: Blood Vessels, Continued

PHYSIOLOGY OF CIRCULATION

Blood Pressure in Vessels



Two Factors Affecting Blood Pressure

BP = CO x PR

1. **Cardiac Output** (CO) is the *main determinant* of blood pressure. CO is the amount of blood pumped by the heart each minute, roughly equal to blood volume. If CO ↑, then BP ↑.
   - **Plasma** is about 55% of blood volume and is mostly water.
   - **Formed elements** are about 45% of blood volume and are mostly RBCs (hematocrit).
2. **Peripheral Resistance** (PR): includes all factors that oppose or inhibit blood flow (such as friction, drag, vessel diameter).

   Three sources of peripheral resistance are:

   1. **Blood viscosity =** blood thickness
      a. "thick" blood (more cells and less plasma) provides more resistance to flow – ↑ BP
      b. "thin" blood (less cells and more plasma) provides less resistance to flow – ↓ BP
   2. **Vessel length**
      a. long vessel – provides more resistance to flow – ↑ BP
      b. short vessel – provides less resistance to flow – ↓ BP
   3. **Vessel diameter*** *controlled by vasomotor center in medulla*
      a. decreased (small) vessel diameter – provides more resistance to flow – ↑ BP
      b. increased (large) vessel diameter – provides less resistance to flow – ↓ BP

Chapter 18: Cardiovascular System: Blood Vessels, Continued

This page is t h i c k ! Make sure you spend time talking through it!

SHORT-TERM CONTROL OF BLOOD PRESSURE: ANS

- The **cardiovascular center** is located in the **medulla oblongata**. The cardiovascular center has two parts:
  - **Cardiac center** is the external control center for heart rate via the SA node
  - **Vasomotor center** (VC) controls arteriole vessel diameter and regulates blood pressure
- The cardiovascular center transmits impulses along **sympathetic** pathways to **BOTH** the heart and vessels. Sympathetic nervous system response increases the release of epinephrine and norepinephrine. Parasympathetic innervation **ONLY** travels to the heart via the vagus nerve. There's **NO parasympathetic innervation** to the vessels.

The cardiovascular (cardiac and vasomotor) center control is modified in response to input from receptors:

- **Higher brain centers –** your emotional state can override the vasomotor center
- **Baroreceptors** are located in the aorta & common carotid arteries. Baroreceptors detect blood pressure changes.
- **Chemoreceptors** are located in the aorta & common carotid arteries. Chemoreceptors detect blood chemistry changes (specifically oxygen, carbon dioxide, and hydrogen ion levels - pH).

Negative Feedback Control of Heart Rate and Blood Pressure

These are compensation mechanisms – ways to fix a problem with blood chemistry or blood pressure.

Stimulus	**Receptor**	**Cardiovascular center response:**	**Heart rate will…**	**Blood pressure will…**
High BP	Baroreceptor	Decrease sympathetic stimulation to heart and vessels Increase parasympathetic stimulation to the heart (only)	Decrease (SA node fires more slowly)	Decrease (Vasodilation)
Low BP	Baroreceptor	Increase sympathetic stimulation to heart and vessels Decrease parasympathetic stimulation to the heart (only)	Increase (SA node fires more quickly)	Increase (Vasoconstriction)
Any one of these: High O_2 Low CO_2 Alkalosis	Chemoreceptor	Decrease sympathetic stimulation to heart and vessels Increase parasympathetic stimulation to the heart (only)	Decrease (SA node fires more slowly)	Decrease (Vasodilation)
Any one of these: Low O_2 High CO_2 Acidosis	Chemoreceptor	Increase sympathetic stimulation to heart and vessels Decrease parasympathetic stimulation to the heart (only)	Increase (SA node fires more quickly)	Increase (Vasoconstriction)

Use this information to complete the worksheet on the next page.

Chapter 18: Cardiovascular System: Blood Vessels, Continued

Describe the negative feedback loops used to maintain normal blood pressure.

Baroreceptors and regulation of blood pressure:

HIGH BP: Mrs. M has polycythemia. Polycythemia caused increased blood viscosity and blood pressure. Explain how the cardiovascular center attempts to restore both blood pressure and heart rate to normal.

Stimulus: high blood pressure

Receptors: baroreceptors will tell the cardiovascular center that BP is too high

Control center: the cardiovascular center will decrease sympathetic stimulation; increase parasym. stimulation

Effectors (Response): SA node fires more slowly and heart rate decreases; vessels dilate and the BP decreases

LOW BP: Mr. S has low blood pressure due to dehydration. He drank too much alcohol last night. Map the negative feedback response of the cardiovascular center to restore both blood pressure and heart rate to normal.

Stimulus: _____

Receptors: _____

Control center: _____

Effectors (Response): _____

Chemoreceptors and regulation of blood pressure:

HIGH BLOOD pH: Mr. J took too many alkaline antacids due to his upset stomach; thus he's heading into alkalosis. Discuss the response of the cardiovascular center to alkalosis.

Stimulus: _____

Receptors: _____

Control center: _____

Effectors: _____

HYPERCAPNIA: Ms. L is exercising and experiencing an increase in carbon dioxide levels as well as lactic acidosis. Map the response of the cardiovascular center to these blood chemistry changes.

Stimulus: _____

Receptors: _____

Control center: _____

Effectors: _____

HYPOXIA: Mrs. Z took a trip to the mountains. She felt lightheaded and was hypoxic. How will the cardiovascular center respond to hypoxia?

Stimulus: _____

Receptors: _____

Control center: _____

Effectors: _____

Chapter 18: Cardiovascular System: Blood Vessels, Continued

SHORT-TERM CONTROL OF BLOOD PPRESSURE: CHEMICALS

- **Histamine**: vasodilator (produced during the inflammatory response which causes BP to decrease).
- **Nitrous oxide**: vasodilator (produced by the lining of blood vessels).
- **Nicotine**: vasoconstrictor (tobacco products)

HORMONAL CONTROLS OF BLOOD PRESSURE

- **Epinephrine and norepinephrine**: hormones produced by the adrenal medulla during periods of stress.

  Epi and NE cause:

  - CO to increase
  - Vasoconstriction of all vessels (except skeletal & cardiac)
  - Increased BP

  Beta blockers block epinephrine and norepinephrine from binding to receptor sites on target cells. Some beta blockers specifically bind receptors on the heart while others bind receptors specifically on smooth muscle in vascular walls. *What effect does a beta blocker have on heart rate and/or blood pressure*? _____

- **Antidiuretic hormone (ADH)…**also known as **vasopressin:** Made by hypothalamus, released by posterior pituitary. This hormone simulates the kidneys to retain water. The kidneys provide long-term control of blood volume and pressure. *Why do you think a patient might receive vasopressin rather than epinephrine as a way to increase BP*?_____

  ADH causes:
  - Vasoconstriction of systemic vessels if there is a severe blood loss (hemorrhage)
  - Increased BP

- **Angiotensin II**: Renin is released by the kidneys which ultimately makes angiotensin II.

  Angiotensin II causes:
  - Vasoconstriction
  - Increased blood pressure
  - Stimulates the release of aldosterone (promotes sodium reabsorption)

  ACE inhibitors (angiotensin converting enzyme inhibitors) prevent the formation of angiotensin II from angiotensin I (BP medication). In turn, aldosterone is not made. *What effect does the ACE inhibitor have on blood pressure?* _____

- ***Atrial natriuretic peptide* (ANP):** produced by the right atrium of the heart. ANP works as an antagonist to another hormone called aldosterone

  ANP causes:
  - Decreased blood pressure
  - Decreased blood volume
  - Vasodilation

Chapter 18: Cardiovascular System: Blood Vessels, Continued

Review of the Physiology of Circulation

Indicate if the following factors will INCREASE BP or DECREASE BP.

Cause	Effects
Atrial natriuretic peptide	
Antidiuretic hormone	
Epinephrine	
Angiotensin II	
Aldosterone	
Nicotine	
Histamine	
Increased levels of CO_2	
Decreased levels of O_2	
Acidosis	
Vasoconstriction	
Vasodilation	
Upset or angry, emotional	
Increased peripheral resistance	
Increased heart rate	
Decreased blood volume	
Increased blood volume	
Taking a deep breath	
Increased cardiac output	
Hemorrhage (loss of blood)	
Increased stroke volume	

For Discussion:

1. Identify two hormones that increase blood pressure and explain how each hormone fulfills its job.
2. Briefly explain the effects of drinking alcohol and smoking cigarettes on blood volume and blood pressure. How does the body regulate blood pressure when people smoke and drink at the same time?
3. Explain the effect of epinephrine on heart rate.
4. How does the vasomotor center (VC) respond to increased blood pressure to restore homeostasis?
5. A hypoxic patient has a fast heart rate. Explain how the vasomotor center (VC) was involved.
6. Name and explain 2 factors that aid in venous return of blood to the heart.
7. Standing up quickly after being in a horizontal position can cause dizziness and light-headedness. What is the name for this type of low blood pressure? Explain why this is more likely in a warm room than in a cool room.

Chapter 18: Cardiovascular System: Blood Vessels, Continued

FLUID MOVEMENTS – BULK FLOW BASICS

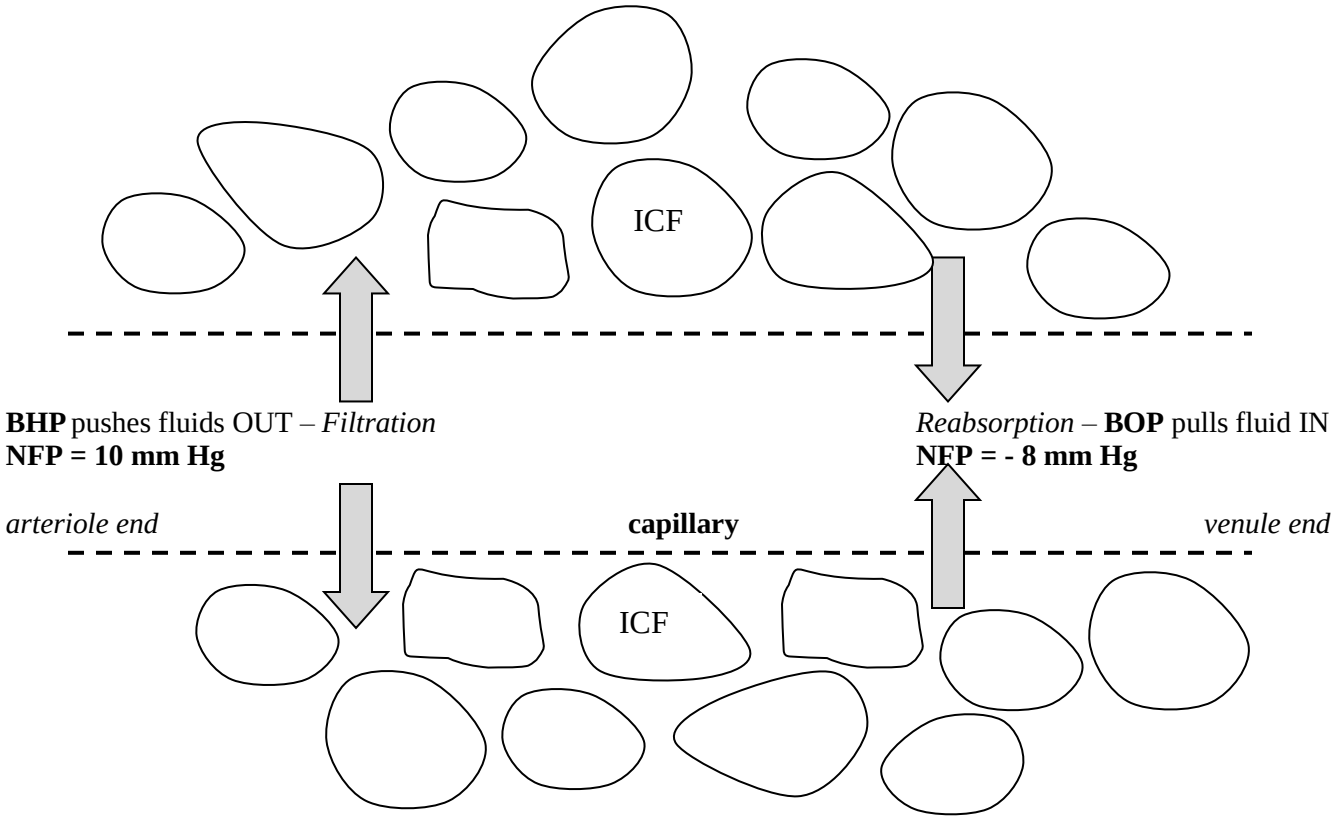
Overview: Fluid is forced out of capillaries at the arterial end (called **filtration**) due to BHP, but most of the fluid returns to the capillaries at the venous end (called **reabsorption**) due to BOP.

Two Battling Pressures

Hydrostatic Pressure (HP)	**Osmotic Pressure (OP)**

• In the vessel, it's the same as blood pressure (BP)
• Created by presence of **fluids**
• **PUSHES** fluids from high pressure to low pressure
• Two types
  ○ Blood hydrostatic pressure (BHP) also known as capillary hydrostatic pressure (HP_C)
  ○ Hydrostatic pressure of the interstitial fluid (HP_{IF})
	• Not blood pressure! Remember osmosis?
	• Created by presence of **solute & proteins** in fluid
	• **PULLS** fluids toward the highest solute concentration (highest osmotic pressure)
	• Two types
	  ○ Blood osmotic pressure (BOP) also known as capillary (or colloid) osmotic pressure (OP_C)
	  ○ Osmotic pressure of the interstitial fluid (OP_{IF})

NET FLOW at arterial end is **OUT** **NET FLOW** at venous end is **IN**



Chapter 18: Cardiovascular System: Blood Vessels, Continued

Review of the Bulk Flow and Capillary Exchange

1. How does blood hydrostatic pressure (BHP) change from the arterial end of the capillary to the venous end?

_____

2. The drop in _____ (*which pressure?*) allows interstitial fluid (IF) to travel into the capillary at the venous end.

3. What effect do plasma proteins, such as albumin, have on fluids in the interstitial space? _____

4. Why does fluid return to the capillary at the venous end but not at the arterial end? _____

_____

5. What happens to any fluids that are not returned to circulation at the venous end of the capillary? _____

_____

6. Which pressure (*BOP* or *BHP*) is responsible for filtration at the arterial end of the capillary? _____

7. Which pressure (*BOP* or *BHP*) is responsible for reabsorption at the venous end of the capillary? _____

8. What would happen to fluid transport if BHP exceeded BOP at the *venous* end of the capillary? _____

_____

9. If escaped plasma proteins cannot be picked up by the lymphatic system, which pressure in the capillary is affected? _

_____

10. If interstitial fluid cannot be reabsorbed by the capillary or the lymphatic system, which pressure in the capillary is affected?_____

11. The liver makes plasma proteins such as albumin. Why would liver disorders lead to edema? Name one specific type of pressure involved in capillary exchange that would be affected by liver disorders. Why would that particular pressure be affected? _____

12. Explain how high blood pressure (BHP) causes edema._____

13. How would drinking salt water affect osmotic pressure of the capillary (BOP)?_____

14. How could changes in osmotic and hydrostatic pressure cause edema?_____

15. What situations can you think of that might increase the return of fluids to the capillary at the venule end?

_____

_____

Chapter 18: Cardiovascular System: Blood Vessels, Continued

Edema: when fluid output (filtration) exceeds fluid input (reabsorption) there is an abnormal increase in interstitial fluid, causing the tissues to swell. Several main causes of this condition:

1) ↓ plasma proteins due to liver disease, malnutrition, or kidney disease. This lowers the BOP.
2) Obstructed venous return (due to blood clots or cardiac failure) → raises HP_{IF} (more fluid, not more solutes)
3) Increased permeability of capillaries due to infection, inflammation or chemicals. This raises the OP_{IF} as more proteins leak out into the tissues.

DISORDERS of BLOOD VESSELS

1. **Shock:** failure of cardiovascular system to deliver adequate amounts of O_2 & nutrients to meet the needs of body tissues. (If it persists, cells die & organs are damaged).
   a) Symptoms of Shock: weak, thready pulse, skin cold & clammy & cyanotic. ↑ rate & depth of breathing, ↑ thirst, ↓ urine output, restlessness, coma. *Read about anaphylactic shock in your book.*
2. **Aneurysm:** thin, weakened section of blood vessel wall that balloons outward; high risk of rupture causing massive hemorrhage, shock, stroke, even death. To repair an aneurysm, clamp artery above & below, excise aneurysm and suture in a graft
3. **Hypotension**: systolic pressure below 100 mm Hg. *Orthostatic hypotension* can occur upon standing.
4. **Hypertension:** chronically high blood pressure (SBP > 140 and DBP > 90)
   a) Cause: several factors contribute: diet (high sodium saturated fat, cholesterol) obesity, smoking, heredity.
   b) Dangers: heart works harder to pump against ↑ resistance → myocardium enlarges → needs more O_2 (if can't get it → angina or MI). Strain on cerebral artery may lead to stroke. Also leads to renal failure & vascular diseases.
   c) Control by: restrict salt, fat, & cholesterol intake in diet; lose weight; antihypertensive drugs (diuretics, beta blockers, calcium chemical blockers)

5. **Stroke –** region of brain dies due to lack of blood supply (and oxygen) to an area. Strokes are '*brain attacks'* like MI are '*heart attacks*.'

   Two types of strokes:

   1. **Ischemic strokes** are due to a blockage in a blood vessel in the brain (*least common type of stroke*)
   2. **Hemorrhagic strokes** are due to a burst brain aneurysm, or a weakened blood vessel

   What are the symptoms of a stroke (**www.stroke.org)**? _____

   _____

6. **TIA** (transient ischemic attack) – short term loss of oxygen to the brain. Symptoms mirror those of stroke

   How long would the symptoms of a TIA last (**www.stroke.org)**? _____

7. **Atherosclerosis**: narrowing of arteries due to the accumulation of cholesterol + calcium (plaque). It starts by picking up LDL (low density lipoproteins) and then accumulates fibrous tissue and platelets. The end stage is **arteriosclerosis** which is hardening of the arteries due to loss of elasticity and deposits. Thrombus can form and completely block the vessel.

Chapter 18: Cardiovascular System: Blood Vessels, Continued

Review of the Blood Vessels

_____1. Pressure is highest in:
A. arteries
B. arterioles
C. capillaries
D. venules
E. veins

_____2. Which of these pressures is exerted by fluid in capillaries to push fluids out of the capillary?
A. interstitial fluid hydrostatic pressure
B. capillary colloid osmotic pressure
C. capillary hydrostatic pressure
D. interstitial fluid osmotic pressure
E. both A and C

_____3. Which of these vessels has the valves to prevent the backflow of blood?
A. aorta
B. veins
C. capillaries
D. arteries
E. arterioles

_____4. Fluid is typically pushed out of a capillary at the _____ end but moves back into the capillary at the ____ end.
A. arteriole…venule
B. low pressure…high pressure
C. high pressure…high pressure
D. venule…arteriole
E. superior…inferior

_____5. Which of these hormones promotes vasodilation?
A. aldosterone
B. ADH
C. ANP
D. epinephrine
E. angiotensin II

_____6. Which of these is the main determinant of blood pressure?
A. heart rate
B. stroke volume
C. peripheral resistance
D. cardiac output
E. vessel diameter

Answers: 1A, 2C, 3B, 4A, 5C, 6D

Chapter 20: Lymphatic System

FUNCTIONS

1. Return approximately 3 L of escaped fluids and plasma proteins to the circulatory system each day.
2. Play a role in immune system responses (through action of WBC) and removes foreign material from lymph.

COMPOSITION OF LYMPH

Lymph is the fluid found in the lymphatic vessels and contains**:**

- **Escaped plasma**: fluid of the blood stream that contains water, solutes, amino acids, proteins
- **Interstitial fluid**: fluid found between cells and tissues (outside of cells)
- **Plasma proteins** escaped from the blood that are now found in the interstitial fluids
- **Lymphocytes**

NOT in lymph: RBC and platelets are *not* supposed to be in lymph

LYMPH VESSELS

The **lymphatics** are a system of drainage vessels that collect excess lymph & return it to the bloodstream. Once fluid is in these vessels, it is called lymph.

Lymph vessels:

1. Lymph vessels form a **one-way** system that flows toward the **heart**.
   a. **Anatomy of lymph vessels**: thin walls, valves, and low pressure (pumpless system) helps fluid return to lymph vessels (*sound familiar?*)
   b. **Since they are low-pressured and thin, several factors assist with the return of lymph to the heart:**
      1. Skeletal muscle pump (contractions)
      2. Respiratory pump (breathing)
      3. Smooth muscles in the walls of the lymphatics
      4. Valves in larger lymphatic vessels

2. **Lymph capillaries** travel between tissue cells and blood capillaries in the loose connective tissue and absorb the leaked fluid and proteins. These capillaries are very small in diameter; they are very permeable. Cells on the capillaries overlap forming **minivalves** that act as one-way swinging doors.

3. Once collected by the lymph capillaries, lymph flows next into larger lymphatic vessels, and from there into lymphatic ducts. Lymph is eventually collected into 1 of 2 large ducts that empty into the venous circulation at the junction of the subclavian & jugular veins in the neck…*see next page*

4. What do you think happens to lymph if there is a blockage in a lymphatic vessel? _____

_____

And, what happens to CO and BP when lymph cannot be returned to the lymphatic vessel? _____

_____

Chapter 20: Lymphatic System, Continued

PATHWAY OF LYMPH BACK TO THE HEART

Both the L and R ducts eventually empty the lymph into the L and R subclavian V on their own side of the body.

***Right* side of head, right side of the thorax, and right arm:** lymph is transported through lymph vessels until it returned to the thoracic region.

Right lymphatic duct drains lymph from the right arm, right side of head and thorax and returns it to

- R lymphatic duct
- R subclavian vein
- R brachiocephalic vein
- SVC
- R atrium of heart

***Left* side of head, left side of the thorax, left arm, and <u>both</u> legs** return lymph to the **left thoracic duct** in the chest which dumps lymph in the:

- L thoracic duct
- L subclavian vein
- L brachiocephalic vein
- SVC
- R atrium of heart

LYMPH NODES

Functions

1. Clean lymph of bacteria, viruses, and cancer cells
2. Produce lymphocytes (a type of WBC) that function in the immune response

   Any items missed by the lymph nodes can be returned to blood circulation.

   *Lymph nodes can become swollen and inflamed (*buboes*) when large numbers of bacteria and viruses become trapped; also they can become secondary cancer sites (called lymphoma—lymph nodes are swollen but not sore/painful).*

Locations

1. Scattered among lymph vessels in connective tissue
2. Three main areas of lymph nodes: 1) cervical 2) axillary 3) inguinal

Cells Housed in Lymph Nodes

1. **Macrophages** in the nodes remove and destroy microbes & debris that entered the lymph from infected tissues, preventing them from entering the blood.
2. **Lymphocytes** in the nodes monitor the lymph for the presence of antigens and launch an immune attack.

Lymph Node Structure

- Kidney-shaped, less than 1 inch long, buried in connective tissue
- Surrounded by a fibrous capsule from which strands, called **trabeculae,** extend inward to divide the node into a number of compartments.
- Lymph enters the nodes via afferent lymphatic vessels, and exits via efferent vessels. There are fewer efferent vessels, so lymph flow stagnates within the lymph node, allowing time for cleaning.

Chapter 20: Lymphatic System, Continued

Composition of the Lymphoid Organs

Lymphoid organs are collections of lymphatic tissue made of a type of loose CT and have two main types of cells:

a. **Lymphocytes**: the main warriors of the immune system, they arise in red bone marrow. They develop into one of 2 types:

1. **T cells**: directly attack & destroy foreign cells (cellular immunity)
2. **B cells**: develop into plasma cells which in turn secrete antibodies that immobilize the foreign substance (antigen) until it can be phagocytized. (humoral immunity)

b. **Macrophages** : large cells that phagocytize foreign substances and help to activate T cells.

Spleen

Location: on the left side of the abdominal cavity

Functions:

- Proliferation of lymphocytes during immune response.
- Cleanses blood of old/defective red blood cells, debris, foreign matter, bacteria and viruses.
- Stores breakdown products of red blood cells for later reuse.
- Stores blood platelets (called a *blood reservoir*)

Thymus

Location: Found beneath the sternum overlying the heart

Functions:

- Produces thymosin which enables the immune system to function against specific pathogens
- The size of the thymus varies with age. Prominent in infants, it enlarges during childhood, but stops growing in adolescence and then begins to atrophy, being almost entirely replaced by fibrous tissue in old age!
- The thymus is the only lymphoid organ that does **not** *directly* fight antigens.

Tonsils

Location: Found form a ring of lymphatic tissue around the entrance to the pharynx where they appear as swellings of the mucosa; we have 5 tonsils total. They are named according to location:

- **Palatine tonsils (2)**
- **Lingual tonsils (2)**
- **Pharyngeal tonsils** (**adenoids**) **(1)**

Function: gather and remove microbes entering the pharynx in inhaled air or in food.

Peyer's patches

Location: walls of the intestine (structurally similar to tonsils)

Function: Macrophages capture and destroy bacteria – prevent them from entering intestinal wall→ bloodstream

- Peyer's patches, the appendix, and tonsils are part of a collection of small lymphoid tissues referred to as: **mucosa-associated lymphatic tissue (MALT)** which acts to protect the upper respiratory and digestive tracts

Chapter 20: Lymphatic System, Continued

Review of the Lymphatic System

Lymphatic System Anatomy

Identify these parts or features of the lymphatic system's anatomy.

_____1. the matrix of blood that composes lymph is called:

_____2. the fluid that is found between tissues is called:

_____3. these vessels of the lymph system return lymph to the bloodstream

_____4. these larger vessels have valves and carry lymph to the heart

_____5. lymph is composed of ___ and ___

_____6. the function of a ___ is to clean lymph of bacteria and viruses

_____7. these types of blood cells are found in lymph nodes

_____8. these vessels are thin walled and have minivalves

_____9. lymph flows to the right lymphatic duct on the ___ side of the body

_____10. lymph flows to the left thoracic duct directly into the ____ vein

Answers: 1. plasma, 2. interstitial fluid, 3. lymphatic veins, 4. lymphatic veins, 5. escaped plasma and interstitial fluid, 6. lymph node, 7. white blood cells (macrophages), 8. lymph capillaries, 9. right, 10. left subclavian

Review of the Lymphatic System Organs

Identify these organs that belong to the lymphatic system.

_____1. organ stores red blood cells in case of hemorrhage

_____2. lymph organs are found in the back of the throat (pharynx)

_____3. organ is found over the heart and doubles as an endocrine gland

_____4. organ destroys worn-out blood cells

_____5. parts of the lymphatic system are found around the small intestine

_____6. organs that cleanse lymph of bacteria, viruses, cancer cells

_____7. organs found clustered around the inguinal, cervical, and axillary regions

Answers: 1. spleen, 2. tonsils, 3. thymus gland, 4. spleen, 5. Peyer's patches, 6. lymph nodes, 7. lymph nodes

For Discussion

1. Describe how lymph returns to the heart. What route does it follow once it's in the bloodstream?
2. Compare and contrast the lymphatic system vessels to the cardiovascular system veins.
3. Explain the role of the lymph nodes in the immune and lymphatic system.
4. Describe what items compose lymph. What is not found in lymph?
5. How would one differentiate between cancerous lymph nodes and those simply infected by microorganisms?
6. What is MALT? Which lymphoid organs belong to the MALT system?
7. Is life possible without the spleen? Which organ(s) pick up the spleen's jobs?
8. Women who have experienced a left breast mastectomy may have had her left axillary lymph nodes and associated vessels removed. Why might she experience edema in her left arm?

Chapter 20: Lymphatic System, Continued

Review of the Lymphatic System

_____1. The organ primarily responsible for filtering debris from blood is the:
A. tonsil
B. spleen
C. pancreas
D. Peyer's patches
E. thymus gland

_____2. White blood cells are trained in the ____ during youth.
A. tonsils
B. thymus gland
C. MALT
D. lymph nodes
E. Peyer's patches

_____3. Lymph from the _____ returns to the heart via the left thoracic duct and left subclavian vein.
A. left arm
B. right leg
C. right arm
D. head
E. thorax

_____4. Lymph enters the lymph node for cleansing at the:
A. afferent vessel
B. right subclavian vein
C. efferent vessel
D. venule
E. left lymphatic duct

_____5. Only the _____ filter and cleanse lymph.
A. spleen
B. lymph nodes
C. tonsils
D. Peyer's patches
E. thymus gland

_____6. Lymph travels in one direction—toward the:
A. spleen
B. heart
C. thymus gland
D. brain
E. stomach

Answers: 1B, 2B, 3A and B, 4A, 5B, 6B

Chapter 21: Respiratory System

RESPIRATORY SYSTEM ORGANS

NOSE

ANATOMY

- **External:** made of bone (**nasal bones** form bridge) and cartilage (at the tip); covered with skin & lined with mucus membrane. The 2 openings on the inferior surface are called external nares (nostrils).
- **Internal:** incoming air enters the *nasal cavity* which is divided into right & left sides by the *nasal septum* (made of hyaline cartilage (anterior) & perpendicular plate of ethmoid). Nasal concha (turbinates) are formed by the ethmoid bone.
  - The roof of the nasal cavity is formed by the **maxilla bone** which separates nasal cavity from cranial cavity.
  - Afferent sensory nerves travel through openings of the **cribriform plate** to connect to the brain and enable one to smell.
  - The floor is formed by the palate, which separates it from the oral cavity. It connects posteriorly with the nasopharynx through 2 *internal nares.*
    - **Hard palate** – formed by the maxillary processes and palatine bones
    - **Soft palate** – formed by muscles, not bones

PHYSIOLOGY

- **Filters:** coarse hairs lining anterior nasal cavity filter out large dust particles. Mucus traps dust, bacteria, and debris; cilia sweep this mucus back into the pharynx for swallowing.
- **Warms:** Veins in the nasal mucosa warm incoming air.
- **Humidifies:** Mucus & serous-secreting epithelium lines cavity & moistens incoming air
- **Smell:** olfactory receptors lie in epithelium lining roof of nasal cavity; they send signals via cranial nerve #I (olfactory nerve) to the olfactory area in the brain (temporal lobe)

- **Paranasal sinuses**: located in four bones: maxilla, ethmoid, sphenoid, frontal. These sinuses warm and moisten the air entering the nasal cavity.

PHARYNX (Throat)

ANATOMY

- Funnel shaped, muscular tube that connects the internal nares to the voicebox (larynx)
- There are three sections:
  - **Nasopharynx**: "nose-throat region" – uppermost region that runs from internal nares (behind nasal cavity) to roof of mouth.
    - Passageway for *air* only.
    - 2 openings into the Eustachian (pharyngotympanic/auditory) tubes that connect throat to middle ear.
    - Functions to equalize pressure.

Chapter 21: Respiratory System, Continued

PHARYNX (Throat)

ANATOMY, continued

- Two masses of lymph tissue on the posterior wall (adenoids or pharyngeal tonsils) trap & destroy pathogens entering in the air.
- The **uvula** (end of the soft palate) hangs into the nasopharynx; it moves superiorly during swallowing to prevent food from entering the nasal cavity.

- **Oropharynx**: the middle region, behind the mouth (from the soft palate to the epiglottis). Archway between it & the mouth is called *fauces*. This region contains the palatine & lingual tonsils.
- **Laryngopharynx**: lowest region; from epiglottis to larynx (anteriorly) and esophagus (posteriorly)

PHYSIOLOGY: pharynx region as a passageway for both food (digestive system) & air (respiratory system).

LARYNX (Voice box)

ANATOMY

- Short passageway connecting pharynx with trachea; in the middle neck, anterior to vertebrae $C_3 \rightarrow C_6$. The walls are made of hyaline cartilage. The most prominent anterior wall is composed of the thyroid cartilage ("Adam's Apple").
- Lined with ciliated and mucous-producing cells.
- **Epiglottis:** leaf-shaped piece of cartilage lying on top of larynx; it moves up & down like a trap door to prevent food from entering the trachea; during swallowing, it closes over the **glottis** (opening).
- **Vocal folds (true vocal cords)** vibrate to produce sound.

PHYSIOLOGY

- **Voice Production:** Exhaled air from lungs causes the vocal cords (pair of folds in mucus membrane lining larynx) to vibrate; this generates sound waves. The cords are attached to skeletal muscles, which control pitch by adjusting the tension. These sound waves are converted to speech by using the muscles in the pharynx (vowels), face, tongue & lips (consonants). **Laryngitis**: Inflammation of vocal cords in larynx.

This is commonly missed on tests!

- **Valsalva's maneuver**: the vocal folds act as a sphincter to close off the respiratory system; causes intra-abdominal pressure to rise (empty rectum and stabilize trunk with lifting something heavy). This maneuver stimulates the vagus nerve and lowers heart rate.
- Provide an open (*patent*) airway
- Route air and food into proper channels

For Discussion:

1. Provide three reasons supporting why we should breathe through the nose, not the mouth.
2. What is the function of the larynx in the respiratory system?
3. What is the role of the epiglottis?

Chapter 21: Respiratory System, Continued

TRACHEA (wind pipe):

ANATOMY

- 4**"** long tubular passageway for air (1" wide) anterior to the esophagus in the neck; from larynx to midthorax, where it divides into the right & left primary bronchus. (*Bronchi* pleural.)
- 16-20 C-shaped rings of hyaline cartilage encircle the trachealis muscle walls to give the trachea rigid support, so it doesn't collapse & obstruct airways. The open part of the ring faces the esophagus, allowing it to expand when swallowing food.
- Lined with **ciliated** cells and mucous-producing cells (goblet cells); composed of **pseudostratified ET**
- The last part of the trachea is the **carina** where it branches into the two bronchi.
- The smooth muscle walls are innervated by the autonomic nervous system

PHYSIOLOGY

- Transports air to and from the lungs.
  - Under stress, the sympathetic NS causes the diameter of the trachea to **dilate** (increase diameter).
  - When resting, the parasympathetic NS causes the diameter of the trachea to **constrict** (decrease diameter).

BRONCHI

ANATOMY

- At the level of T_7, the trachea divides into a right & left **primary bronchus** (pl. = bronchi), each running to the medial surface of its own lung. The right primary bronchus is wider and shorter than the left primary bronchus.
- Once inside the lungs, the primary bronchi each divide into **secondary (lobar) bronchi** $\rightarrow$ one for each lobe (3 in right lung, 2 in left).
- These secondary bronchi branch again into **tertiary (segmental) bronchi,** which in turn divide into smaller and smaller bronchi.
  - The bronchi are lined with ciliated epithelium and their smooth muscle walls are reinforced with cartilage to keep them from collapsing.
  - Cilia in the trachea & bronchi beat continuously, pushing dirt-laden mucus up to pharynx for swallowing. (Smoking destroys these cilia, so mucus must be removed by coughing).

BRONCHIOLES: smallest branches in the **"respiratory tree"**, they are less than 1 mm in diameter. Lacking cartilage, their *smooth muscle* walls constrict during an asthma attack. The tissue type lining the bronchioles is cuboidal epithelium. Bronchioles also lack cilia so any debris making it to this level must be destroyed by macrophages located in the alveoli.

For Discussion:

1. Why are the right and left primary bronchi not symmetrical in width and length?
2. From the trachea to the bronchioles, where is cilia found? What purpose does the cilia serve?
3. How does asthma affect the diameter of breathing passageways?

Chapter 21: Respiratory System, Continued

ALVEOLI

ANATOMY

- Little **air sacs** clustered in bunches (like grapes) around the ends of microscopic respiratory
- **Thin walls** – simple squamous epithelium (thinner than a soap bubble!) and contain elastin for elasticity.
- **Pulmonary capillaries** surround alveoli; they are also made of simple squamous epithelium. No cilia here.

PHYSIOLOGY: Alveoli are the functional units of the lungs. The alveoli are the sites of gas exchange between inhaled air and the blood.

- **Respiratory Zone Structures**: thin membrane which gases must cross to pass from air sacs into blood:
  - Diffusion carries gases across the thin membrane (oxygen passing from the alveolus into the blood capillary, and carbon dioxide leaving the blood capillary and going into the alveolus).
  - **Surfactant**: phospholipid secreted by type II cells; forms a coat on gas-exposed alveolar surfaces
    - **Function:** surfactant prevents alveoli from collapsing and sticking together (when exhaling). Premature babies often have problems with their lungs collapsing due to insufficient surfactant, known as *hyaline membrane disease*.
  - **Alveolar macrophages**: phagocytic cells that crawl along internal alveolar surfaces removing dust, debris and microbes, keeping alveoli sterile. *Why is it necessary for these macrophages to be present?*

LUNGS

ANATOMY

- Two cone-shaped organs occupying the entire thoracic cavity except the mediastinum (heart, blood vessels, bronchi, esophagus). The lungs are made primarily of elastic connective tissue with 300 million tiny alveoli, making them soft, spongy and elastic organs
- **Apex** – deep to the clavicle (superior tip of lung).
- **Base** – rests on the diaphragm (inferior surface of lung); the lateral surfaces are in close contact with the ribs, and the medial surface of each lung has an indentation called a hilus (bronchus & pulmonary blood vessels enter).
- **Differences** between left and right lungs:
  - **Left lung** has 2 lobes (superior & inferior lobes) and is smaller than the right lung (due to heart orientation)
  - **Right lung** has 3 lobes (superior, middle & inferior).
- **Pleura**: thin, double-layered serous membrane that encloses & protects each lung:
  - **Parietal pleura**: outer layer lining the thoracic wall
  - **Visceral pleura**: inner layer, covering external lung surfaces
  - **Pleural cavity**: tiny space between the 2 layers; filled with a lubricating serous fluid that prevents friction between the membranes during breathing.

MUSCLES INVOLVED IN RESPIRATION:

- **Diaphragm** (stimulated by the phrenic nerve from the cervical nerve plexus)
- **External and Internal Intercostal Muscles**

Chapter 21: Respiratory System, Continued

Pleural Disorders

- **Pleurisy**: inflammation of pleural membrane; causes painful friction, rubbing & stabbing pain during breathing.
- **Pneumothorax**: presence of air in the pleural cavity (between visceral & parietal pleura), such as from a gunshot wound/stabbing. Pneumothorax can cause lung collapse (**atelectasis**) and lungs become non-functional.
- **Pleural effusion**: excess fluid that accumulates between the pleura (fluid on the lungs). Breathing is difficult.

Other Respiratory Disorders (Some diseases have symptoms of both restrictive and obstructive disorders)

Obstructive disorders = exhalation is difficult (**O**bstructive = **O**ut)

- **Emphysema:** destruction of the alveolar walls, loss of surface area. Most often caused by tobacco exposure.
- **Asthma:** inflammation of bronchial passageways; excess mucus and dyspnea.
- **Bronchitis**: inflammation of the bronchial passageways
- **COPD** (chronic obstructive pulmonary disorder/disease) = emphysema + asthma + bronchitis**.**

Restrictive disorders = difficulty getting air into the lungs due to increased resistance to air flow (air flow is *restricted*)

- **Pulmonary fibrosis**: scar tissue
- **Obesity**

Review of Respiratory System Anatomy

Match the letter with the correct phrase

_____1. smallest conducting respiratory passageways within the lungs	A. alveoli
_____2. bone that separates the oral and nasal cavities	B. bronchioles
_____3. voicebox	C. bronchus
_____4. food passageway posterior to the trachea	D. esophagus
_____5. the trachea branches into a right and left primary ____.	E. glottis
_____6. 4" long windpipe that leads into the thoracic cavity	F. palatine and maxilla
_____7. actual site of gas exchange at these air sacs in the lungs	G. parietal pleura
_____8. outermost pleural layer covering the thorax walls	H. larynx
_____9. innermost pleural layer covering the lungs	I. pharynx
_____10. opening to the trachea	J. trachea
_____11. throat	K. visceral pleura

Answers

1B, 2F, 3H, 4D, 5C, 6J, 7A, 8G, 9K, 10E, 11I

Chapter 21: Respiratory System, Continued

PATHWAY OF AIR INTO/OUT OF LUNGS

*Complete the pathway of a molecule of **oxygen** into the blood in the lungs; take it to systemic flow.*

nares → nasal turbinates → _____ → oropharynx → _____ → larynx (glottis) → trachea → _____ → secondary bronchi → tertiary bronchi → _____ → alveoli → pulmonary capillaries → pulmonary venules → _____ → _____ → bicuspid valve → left ventricle → aortic semilunar valve → _____ → arteries → arterioles → capillaries → venules → veins → SVC and IVC → _____

*Complete the pathway of a molecule of **carbon dioxide** out of the blood to be exhaled.*

pulmonary capillary networks surrounding the alveoli → _____

_____

_____

_____

FUNCTION OF THE RESPIRATORY SYSTEM

- Exchange blood gases (oxygen and carbon dioxide) through a blood-air barrier in the lungs.
- *Why do we need to exchange blood gases?* **Cellular respiration** makes ATP from glucose and oxygen. Carbon dioxide is released by the cells.

  Two systems work together to supply O_2 to the cells, and to remove CO_2:

  1) **Respiratory system**: organs that exchange gases between the atmosphere and the blood.
  2) **Cardiovascular system**: blood carries O_2 to tissue cells & removes CO_2

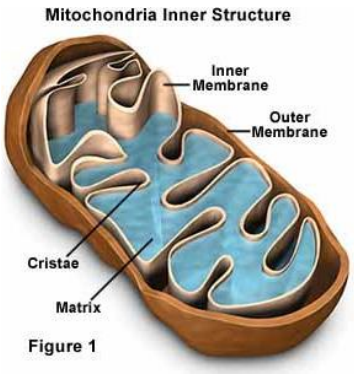


Figure 1

FOUR EVENTS OF RESPIRATION

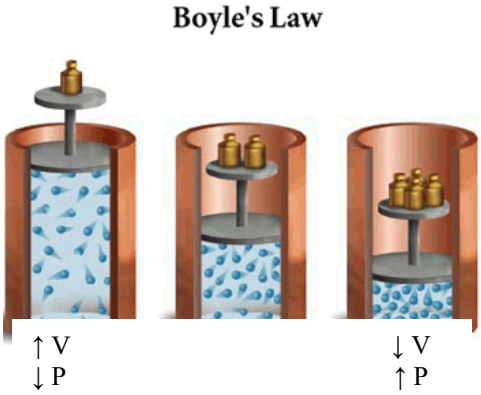
Over the next few pages, we will describe each of these four events that constitute respiration:

1. **Pulmonary ventilation** – breathing in and out
2. **External respiration** – gas exchange occurring at the lungs between pulmonary capillary blood and alveoli
   a. **Oxygen** is loaded into the blood for transport.
   b. **Carbon dioxide** is unloaded into the air for exhalation.
3. **Respiratory gas transport** – movement of gases around the body in the vessels
4. **Internal Respiration** – gas exchange occurring between systemic capillaries and cells of the body
   a. **Oxygen** is unloaded into cells to make ATP.
   b. **Carbon dioxide** is loaded into the blood for transport.

Chapter 21: Respiratory System, Continued

RESPIRATION: PULMONARY VENTILATION
Inspiration (Inhalation) + Expiration (Exhalation)

P = pressure; V = volume



- Volume changes lead to pressure changes
- Pressure changes lead to flow of gases to equalize pressure
- Gases always fill their container (lungs fill the thoracic cavity space)
- Pressure and volume are *inversely proportional*:
  - When volume increases, pressure decreases
  - When volume decreases, pressure increases

Three Pressures:

1. **Atmospheric pressure** is the pressure exerted by air surrounding the body.

760 mm Hg at sea level = 1 atm

2. **Intrapulmonary pressure** is the pressure inside the lungs. The intrapulmonary pressure attempts to equalize with atmospheric pressure.

3. **Intrapleural pressure** is the pressure between the visceral and parietal pleura. This pressure is <u>always</u> less than the intrapulmonary pressure (or negative to it); this negative pressure is major factor that prevents lung collapse. If the ***intrapleural* pressure becomes equal to the atmospheric pressure**, the lungs immediately collapse (**atelectasis**).

SUMMARY TABLE FOR INSPIRATION AND EXPIRATION

Inhalation	Exhalation
Step 1. External intercostals and diaphragm **contract** upon phrenic nerve stimulation	**Step 1.** External intercostals and diaphragm **relax** (no ATP needed) when phrenic nerve stimulation stops
⇩	⇩
Step 2. Volume in the thoracic cavity **increases**	**Step 2. Volume** in the thoracic cavity **decreases**
⇩	⇩
Step 3. Intrapulmonary **pressure decreases** (759 mm Hg)	**Step 3.** Intrapulmonary **pressure increases** (761 mm Hg)
⇩	⇩
Step 4. Air moves air along a pressure gradient into the lungs (HI outside to LO inside)…we **inhale**	**Step 4.** Air exits along a pressure gradient out of the lungs (HI inside to LO outside)…we **exhale**

Physical Factors Influencing Pulmonary Ventilation

1. **Airway resistance** – friction or drag encountered in the respiratory passageways.

2. **Alveolar surface tension** – liquid molecules are drawn closer together by surface tension. To keep surface tension at a minimum, **surfactant** decreases the ability of water molecules to stick together (*remember cohesion?)*.

3. **Lung compliance** – the measure of the stretchiness of lungs since lung compliance is determined by 1) distensibility of the lung tissue and 2) alveolar surface tension

The next two pages are commonly missed items on tests!

Chapter 21: Respiratory System, Continued

CONTROL OF RESPIRATION

Respiratory Center (RC) is a cluster of neurons in the **brain stem** (**medulla oblongata** and **pons**) that control the basic rhythm of respiration via the **phrenic nerve** (part of the cervical plexus).

- **Inspiratory center** (part of the RC) contains neurons that rhythmically discharge impulses for about 2 seconds leading to the contraction of the diaphragm and external intercostal muscles via the _____ nerve. As a result of contraction, the thorax volume _____ & pressure _____, and air rushes into the alveoli (= INHALATION).
- After 2 seconds of impulses, the inspiratory neurons become dormant (inactive) for 3 seconds, during which time expiration results, as the inspiratory muscles relax and the lungs recoil. Expiration is passive (no ATP required).
- The cyclic activity of these neurons (ON 2 seconds/OFF 3 seconds) produces a normal resting respiratory rate of **12-15** breaths a minute in adults (**eupnea)**. *The normal rate will vary by source!*
- **Expiratory neurons** are inactive during quiet respiration. However, during heavy breathing, these neurons send impulses that cause the accessory respiratory muscles to contract → forceful expiration.

Abnormal Breathing Patterns:

- **Dyspnea** is "difficult breathing" or shortness of breath.
- **Apnea** is the absence of breathing. Breathing stops (0 breaths per minute).
- **Hyperpnea** is <u>forceful</u> breathing (including forceful exhalation such as during exercise.)
- **Hyperventilation** is a respiration rate that is <u>faster</u> than normal (12-15 breaths/minute). The **<u>effects</u>** (signs/symptoms) of hyperventilation are:
  - Hypocapnia (too little _____)
  - Respiratory alkalosis (too little _____ ions)
  - Hyperoxia (excess _____, which can be toxic to cells).
- **Hypoventilation** is a respiration rate that is <u>slower</u> than normal (12-15 breaths/minute). The **<u>effects</u>** (signs/symptoms) of hypoventilation are:
  - Hypercapnia (excess carbon dioxide)
  - Respiratory acidosis (excess H+ ions)
  - Hypoxia (too little oxygen) can lead to hypoxemia is little to no oxygen delivery to cells.

The Bicarbonate Buffer System:

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{water}}{H_2O} \leftrightarrow \underset{\text{carbonic acid}}{H_2CO_3} \leftrightarrow H^+ + \underset{\text{bicarbonate ion}}{HCO_3^-}$$

Handled by the: **Respiratory System** **Urinary System**

Chapter 21: Respiratory System, Continued

CONTROL OF RESPIRATION

Regulation of the Respiration Rate: rhythm of the RC can be modified in response to changing blood chemistry:

- **Central chemoreceptors** are located in the medulla and detect changing PCO_2 levels in CSF.
- **Peripheral chemoreceptors** are located in the aortic arch and carotid arteries and detect H+ ion concentration, PCO_2 and PO_2 in arterial blood.
- Changes in PCO_2 are the *most important stimulus* to change rate of respiration; O_2 becomes a stimulus when we hit 60 mm Hg or less.

Negative Feedback Control of Respiration Rate

These are compensation mechanisms – ways to fix a problem with blood chemistry or blood pH.

Stimulus	Receptor	Respiratory Center Response:	Respiration rate will…	How does this help the problem?
Any one of these: • ↑ H+ ions and pH falls causing an acidic condition such as *metabolic acidosis* (diabetes mellitus, exercise) • ↑ PCO_2 = *hypercapnia* (above 45 mm Hg) • ↓ PO_2 = *hypoxia* (below 60 mm Hg)	Chemoreceptor	Increase stimulation to the phrenic nerve. The contraction rate of the diaphragm and intercostal muscles increases.	Increase (Hyperventilation)	Exhale MORE carbon dioxide (which will raise the blood pH) Inhale MORE oxygen.
Any one of these: • ↓ H+ ions and pH rises causing an alkaline condition such as *metabolic alkalosis* (vomiting, taking too many antacids) • ↓ PCO_2 = *hypocapnia* (below 35 mm Hg) • ↑ PO_2 = *hyperoxia*	Chemoreceptor	Decrease stimulation to the phrenic nerve. The contraction rate of the diaphragm and intercostal muscles decreases.	Decrease (Hypoventilation)	Exhale LESS carbon dioxide (which will lower the blood pH) Inhale LESS oxygen.

Chapter 21: Respiratory System, Continued

Use the information from the previous page to complete these problems.

1. Due to kidney failure, Mr. S has a buildup of hydrogen ions in his blood (metabolic acidosis; blood pH = 7.24).
   a. What is the stimulus? _____
   b. How will his respiratory center (RC) compensate to return blood pH to normal? _____
   c. How does the respiration rate change restore blood pH to normal? _____

2. An overdose of antacids (Tums) has caused Ms. M to have too few hydrogen ions in her blood (blood pH = 7.68).
   a. What is the stimulus? _____
   b. How will her RC compensate? _____
   c. How does the respiration rate change restore blood pH to normal? _____

3. Mandy hiked in the high elevations of the Rocky Mountains and experienced some mild hypoxia (PO_2 = 55 mm Hg).
   a. What is the stimulus? _____
   b. How did her RC respond? _____
   c. How does the respiration rate change restore oxygen levels to normal? _____

4. You notice Mr. Z breathing quickly. What blood pH imbalance must have stimulated his RC? _____

5. Aspirin overdose causes overstimulation of the respiratory center.
   a. What blood pH imbalance results? _____
   b. Why? _____

6. A pulmonary embolism can cause hypoxemia (low level of oxygen in the blood).
   a. How will the RC respond? _____
   b. How does the respiration rate change restore normal oxygen levels? _____

7. Cigarette smoke contains carbon monoxide, which impairs the ability of blood to transport oxygen.
   a. What is the stimulus? _____
   b. How will the RC respond? _____
   c. What impact does cigarette smoke have on organs, like the brain? _____

8. Patients who are administered an oxygen cannula (oxygen in the nose) may experience decreased respiration. Why?

   _____

9. Your diabetic neighbor often has very high blood sugar. During these episodes, he experiences ketoacidosis. When you walk in to check on him, what will you notice about his respiration rate to know he's having an episode? _____

   _____

10. If your respiratory system cannot compensate for blood chemistry problems (hydrogen ions, carbon dioxide), which *other* organ system will attempt to restore blood pH to normal? _____

Chapter 21: Respiratory System, Continued

RESPIRATION: GAS EXCHANGE
Internal and External Respiration (Gas Exchange)

Dalton's Law: the total pressure exerted by a mixture of gases is the sum of the pressures exerted independently by each gas in the mixture.

Partial Pressure: the pressure a gas exerts in a mixture of gases is determined by multiplying the percentage of the gas in the mixture by the total pressure of the mixture. Partial pressure is represented by "P" or "p." So, the partial pressure of oxygen is written either as **P**O_2 or **p**O_2. Arterial partial pressure (arterial blood gas or ABG) is represented as PaO_2.

Gas	Percentage of Atmosphere	Partial Pressure mm Hg At Sea Level Outside body	Partial Pressure mm Hg In Lungs and blood	Normal Partial Pressure (mm Hg) (Arterial Blood Gas = ABG)	Partial Pressure mm Hg In Cells
N_2	78.6%	597			
O_2	21%	159 *HIGH*	104	**80 – 100** < 60 is hypoxia	40 *LOW*
CO_2	0.04%	0.3 (inspired air) *LOW*	40	**35 – 45** < 35 is alkalosis > 45 is acidosis	45 *HIGH*
H_2O	0.46%	3.7			
TOTAL	100%	760			

EXTERNAL RESPIRATION: OXYGEN LOADING AND TRANSPORT

Oxygen Loading: Oxygen (O_2) is *loaded* into the blood at the lungs during external respiration and carried in the blood in **two** ways:

1. **Bound to hemoglobin (MOST COMMON METHOD):** Most O_2 (98%) is bound to hemoglobin for transport.
2. **Dissolved in plasma**: since O_2 is relatively insoluble in water, only about 2% is carried in the plasma as a dissolved gas.

Oxygen Transport: Oxygen and Hemoglobin (Hb)

- Each molecule of hemoglobin (Hb) can combine with **4** molecules of oxygen, and the process of oxygen binding is rapid and reversible.
  - When hemoglobin is carrying O_2, it is called **oxyhemoglobin** (HbO_2).
  - Once it has unloaded O_2 during internal respiration, it's called **deoxyhemoglobin** (HHb).
- **Affinity**: Hemoglobin has a preference for binding to oxygen
  - **Fully saturated**: All four heme groups are bound to O_2 (100% saturated)
  - **Partially saturated**: 1 (25% saturated), 2 (50%), or 3 (75%) oxygen molecules are bound to hemoglobin

Chapter 21: Respiratory System, Continued

Oxygen-Hemoglobin Dissociation Curve

- Whether O_2 combines with Hb – *or* is released from Hb – depends primarily on the partial pressure of oxygen (and pH of blood) in the area. This relationship between the partial pressure of oxygen (PO_2) and the percent saturation of hemoglobin (amount of O_2 bound to Hb) is known as the ***oxygen-hemoglobin dissociation curve***:
  - Under resting conditions, only **25**% of the O_2 bound to Hb is unloaded at the tissues. Why? The remaining **75%** is a reserve supply for when oxygen demand increases.

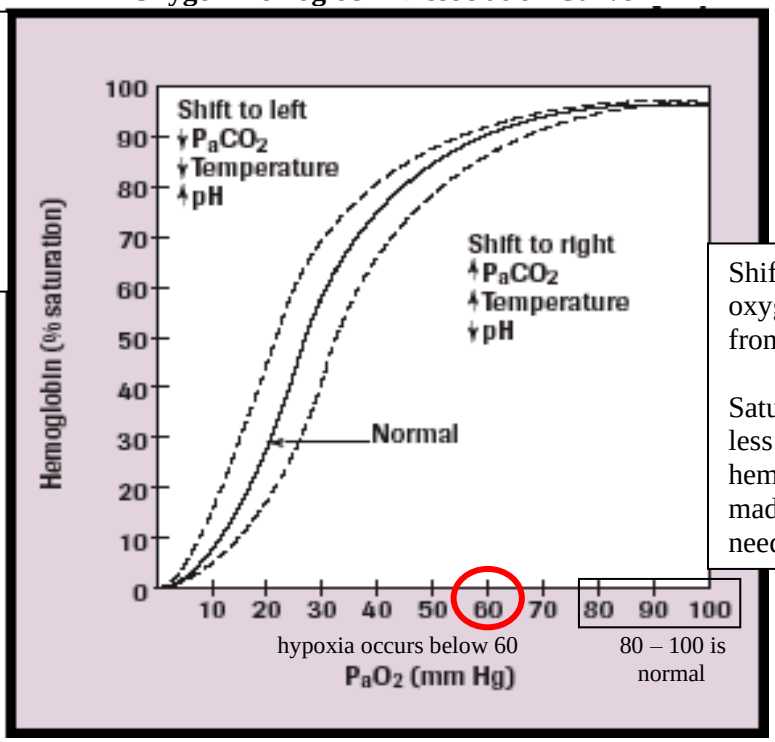
Factors that Influence O_2 Binding to Hb

- Factors that promote unbinding of oxygen from hemoglobin, listed below, will decrease oxygen saturation. Oxygen diffuses into surrounding cells and tissues (we say oxygen is *unloaded*).
  - ↑ PCO_2 (greater than 45 mm Hg)
  - ↓ blood pH (less than 7.35 or acidosis)
  - ↑ temperature (warm temperatures greater than 37° C or 98.6 ° F)
- Factors that promote binding of oxygen to hemoglobin, listed below, increase oxygen saturation. Oxygen stays bound to hemoglobin.
  - ↓ PCO_2 (less than 35 mm Hg)
  - ↑ blood pH (greater than 7.45 or alkalosis)
  - ↓ temperature (cold temperatures less than 37° C or 98.6 ° F)

Oxygen-Hemoglobin Dissociation Curve

Shift to the left prompts oxygen to *bind* to hemoglobin.

Saturation *increases* as hemoglobin holds more tightly to the oxygen.

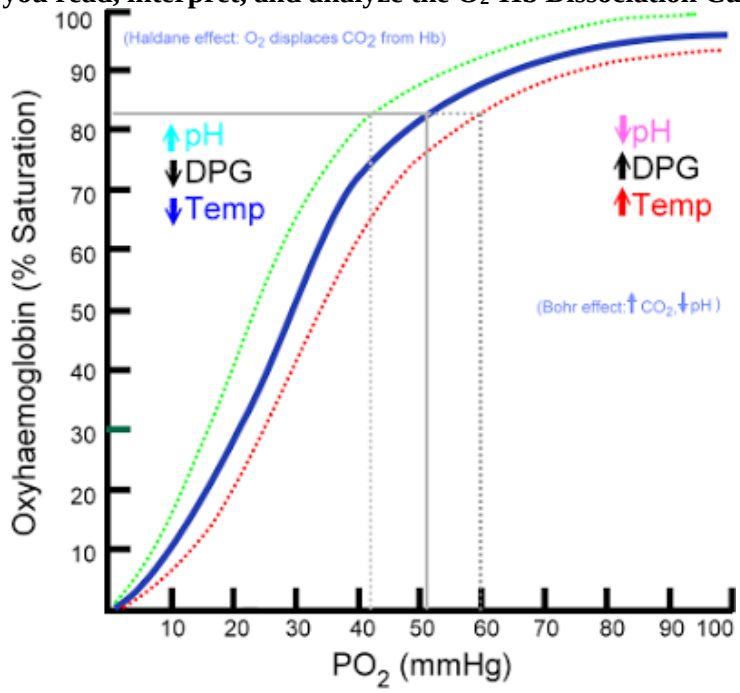


Shift to the right prompts oxygen to *dissociate* (*unbind*) from hemoglobin more readily.

Saturation *declines* - meaning less oxygen is bound to hemoglobin. More oxygen is made available to cells that need to use it.

Chapter 21: Respiratory System, Continued

Can you read, interpret, and analyze the O_2-Hb Dissociation Curve?



1. Predict the saturation of Hb if pO_2 is 51 mm Hg and body temperature is normal. _____

2. Predict the saturation of Hb if pO_2 is 51 mm Hg and body temperature increases. _____

3. Predict the saturation of Hb if pO_2 is 51 mm Hg and a person experiences metabolic alkalosis from excessive vomiting.

_____

How will metabolic alkalosis influence the respiration rate? _____

4. Predict the saturation of Hb if pO_2 is 42 mm Hg and a body temperature is normal. _____

What happens to the percent saturation of Hb when body temperature cools? _____

5. Predict the effect on hemoglobin saturation if a diabetic has metabolic acidosis. _____

_____

6. Compare hemoglobin saturation for normal body temperature (98.6°F) vs a fever (102°F). _____

_____

7. Determine the hemoglobin saturation if pO_2 levels are 60 mm Hg and hypothermia occurs. _____

_____

8. Determine the hemoglobin saturation if pO_2 levels are 60 mm Hg and exercise intensifies. _____

_____

10. A patient with kidney problems experiences metabolic acidosis. What happens to the saturation of hemoglobin if pO_2 levels are 60 mm Hg? _____

Chapter 21: Respiratory System, Continued

Carbon Monoxide Poisoning

- Carbon monoxide (CO) is a colorless, odorless gas found in car exhaust, cigarette smoke, and combustible reactions.
- CO combines with Hb 200 times faster than does O_2 –hemoglobin binds *preferentially* & *irreversibly* with CO over oxygen. When CO is present, it binds to Hb, and prevents oxygen from reaching the tissues. Results: **hypoxia.**
- **Symptoms**: Confusion, throbbing headache.
- **Treatment**? Hyperbaric (high pressure) chamber which provides a high pressure environment to push carbon monoxide off binding sites.

INTERNAL RESPIRATION: CARBON DIOXIDE LOADING AND TRANSPORT

CO_2 is *loaded* into the blood during internal respiration and transported in the blood to the lungs in **three** forms:

1. **Bicarbonate ion (MOST COMMON METHOD of TRANSPORT)** 60 – 70 % of carbon dioxide is converted to HCO_3^- inside RBCs and then transported in the blood plasma.

$$CO_2 \text{ enters the RBCs} + H_2O \leftrightarrow \underset{\text{carbonic acid}}{H_2CO_3} \leftrightarrow H^+ + \underset{\text{bicarbonate ion}}{HCO_3^-}$$

2. **Bound to amino acids of hemoglobin** (not the heme group): 20- 30 % is carried within the RBCs bound to the amino acids as *carbaminohemoglobin*
3. **Dissolved in plasma**: 7- 10 % is carried in the blood plasma as a dissolved gas.

Chapter 21: Respiratory System, Continued

Review of the Respiratory System

Respiratory System Anatomy

Identify these structures of the respiratory system.

_____1. these parts of the trachea branch to enter each lung

_____2. the organ that cleanses, warms, and humidifies air when it enters the body

_____3. the throat

_____4. the vocal cords are found in this structure

_____5. the pleura that is found closer to the lungs

_____6. the pleura that is found farther from the lungs

_____7. small sacs in lungs where exchange of oxygen and carbon dioxide occurs

_____8. mucus is found in this organ to trap debris

_____9. cilia lines this structure to help remove debris

_____10. the primary bronchi branch into these

_____11. this lung has 3 lobes

_____12. the throat region found around the larynx

_____13. the flap of cartilage that covers the trachea when swallowing occurs

Respiration Summary

Identify these events that constitute respiration.

_____1. breathing is simply this event

_____2. the process of exchanging oxygen and carbon dioxide at the lungs

_____3. the movement of oxygen and carbon dioxide through the blood stream

_____4. the process in which the lungs expand to take in air

_____5. this portion of breathing is a passive process

_____6. in order to inhale, these muscles must aid the process

_____7. the internal volume of the lungs increases during this process of breathing

Respiratory System Anatomy Answers: 1. primary bronchi, 2. nose, 3. pharynx, 4. larynx, 5. visceral pleura, 6. parietal pleura, 7. alveoli, 8. nasal cavity, 9. trachea, 10. secondary bronchi (and lungs), 11. right lung, 12. laryngopharynx, 13. epiglottis
Respiration Summary Answers: 1. pulmonary ventilation, 2. external gas exchange, 3. respiratory gas transport, 4. inhalation, 5. exhalation, 6. diaphragm and external intercostals, 7. inhalation

Chapter 21: Respiratory System, Continued

Review of the Respiratory System

For Discussion

1. Explain how changes in volume and pressure lead to inspiration and expiration.
2. Compare and contrast pressure and volume changes in inspiration and expiration.
3. Describe the role of cilia and mucus in the respiratory system.
4. How do hypoventilation and hyperventilation change carbon dioxide levels in the blood?
5. Why is carbon dioxide the most important stimulus for breathing in a healthy person?
6. Explain the role of hemoglobin in transporting blood gases (both carbon dioxide and oxygen).
7. What is the difference between intrapulmonary and intrapleural pressure?
8. Describe the chemical reaction that must occur in order for carbon dioxide to be removed from the blood at the lungs.
9. How is internal respiration different from external respiration? Where does each process occur?
10. Explain Boyle's Law in relation to inspiration and expiration.
11. How does exercise affect oxygen saturation? How does hypothermia affect oxygen saturation?
12. If hemoglobin is fully saturated at 100%, how many oxygen molecules are bound to the molecule?
13. Why does only 25% of O_2 unload into surrounding tissues at rest? What happens to the other 75% of the O_2?
14. If hemoglobin passing through the lungs is 98% saturated with oxygen, what happens to the saturation level as the blood passes through capillaries?

Think about these questions; if you have trouble answering any of them, come see me!

_____1. Most carbon dioxide travels in the blood:
- A. dissolved in plasma
- B. bound to hemoglobin
- C. as bicarbonate ions
- D. as oxyhemoglobin
- E. as carbonic acid

_____2. In order to inhale (inspire) what must happen:
- A. the diaphragm and external intercostals relax
- B. the pressure in the lungs decreases
- C. the volume in the lungs decreases
- D. both pressure and volume decrease
- E. the thoracic cavity pressure equals atmospheric pressure

_____3. Which of the following is NOT a function of the nose?
- A. warms air
- B. humidifies air
- C. cleanses air
- D. smell
- E. gas exchange

_____4. Which of these is the most important chemical affecting respiration?
- A. oxygen
- B. carbon dioxide
- C. nitrogen
- D. hydrogen
- E. nitrous oxide

Answers: 1C, 2B, 3E, 4B

Chapter 22: Digestive System

FUNCTIONS OF THE DIGESTIVE SYSTEM

1. **Digestion**: (both chemical and mechanical) is the breakdown of food into smaller particles
2. **Absorption**: the transport of food particles across the GI wall into the blood stream

BASIC ANATOMY OF THE DIGESTIVE SYSTEM

Organs of the Digestive System

1. **Alimentary Canal** = **Gastrointestinal (GI) Tract = gut**: mouth, pharynx, esophagus, stomach, small intestine, large intestine (opening of large intestine – anus)

   Function: Digests and absorbs digested food fragments

2. **Accessory organs**: teeth, tongue, salivary glands, pancreas, gallbladder, liver

   Function: Contribute secretions that aid in food breakdown

General pathway of food through the body:

mouth → pharynx → esophagus → stomach → small intestine → large intestine → anus

4 Tissue Layers Found in the GI Tract: ***From Esophagus to Large Intestine:***

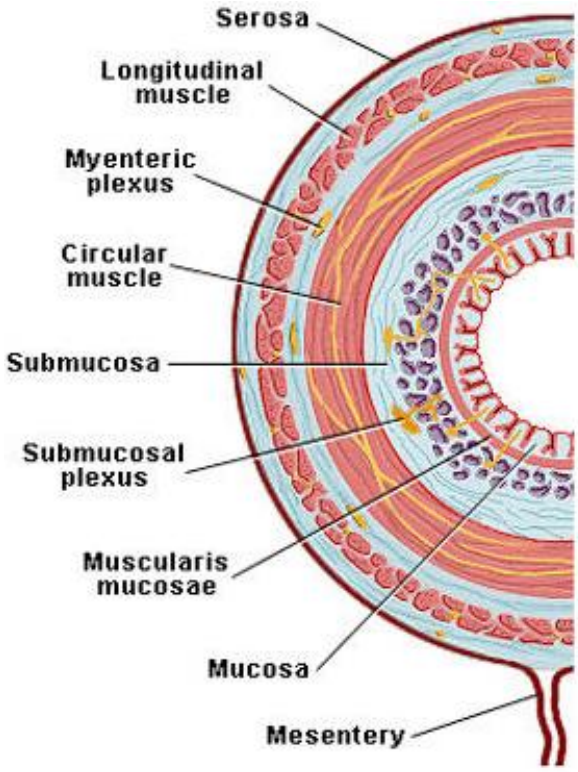
1. **Mucosa** is the innermost layer, lines the lumen of the GI cavity from mouth to anus. Functions to:
   a. **Secrete** mucus and digestive enzymes
   b. **Absorb** end products of digestion into the blood
   c. **Protect** against infection

   Mucosa is simple columnar ET from stomach to anus.

2. **Submucosa** connects the mucosa to the muscularis layer. Contains blood vessels, glands, & autonomic nerves. Its elastic fibers allow the stomach to regain its shape after a large meal.

3. **Muscularis externa** is a muscle layer made of an inner circular layer and an outer longitudinal layer of smooth muscle. Responsible for **peristalsis** and **segmentation** and thickens to form sphincters (valves that prevent the backflow of food and control food passage along to the next organ).

4. **Serosa (mesentery)** is the outermost layer consisting of a single layer of flat serous fluid-producing cells. The peritoneum is formed of connective tissue with a single layer of simple squamous epithelial tissue. The parietal peritoneum covers the wall of the abdominal cavity while the visceral peritoneum is the innermost (covering the organs).



→ **Can you define these terms**? ingestion, mechanical digestion (mastication, peristalsis, segmentation) & chemical digestion, secretion, absorption, excretion, and defecation.

Chapter 22: Digestive System, Continued

ANATOMY AND PHYSIOLOGY OF THE DIGESTIVE ORGANS

MOUTH

ANATOMY

Structure: oral cavity (buccal cavity) lined with mucous membrane

- *labia* (lips) protect the anterior mouth
- *cheeks* form lateral walls
- *hard palate* forms anterior portion of the roof of mouth by the maxilla & palatine bones.
- *soft palate* forms posterior portion of the roof of mouth by skeletal muscle covered with mucous membrane.
- *uvula* is the fingerlike projection of soft palate that hangs down the back of the throat.
- *frenulum* is a fold of mucous membrane which secures the tongue to the floor of mouth
- *teeth* chew (masticate) food and mechanically break it into smaller pieces. There are 32 permanent teeth classified as incisors, canines, premolars, and molars. Each tooth has an enamel-covered crown and a cementum-covered root. The bulk of the tooth is dentin, which surrounds a central pulp cavity.
- *salivary glands* secrete saliva into the mouth through ducts.
    - There are **3 salivary glands**:
        - *parotid glands* lie anterior to the ear between the masseter muscle and skin
        - *submandibular glands* lies under the mandible (lower jaw) at the back of the tongue
        - *sublingual glands* are anterior to the submandibular glands and are under the tongue
    - **Saliva**
        - Output is generally 1 L to 1.5 L per day; slightly acidic at 6.75 to 7.00 pH
        - Contains:
            - 98% water and includes electrolytes (Na^+, K^+, Cl^-, etc.)
            - Mucin forms thick mucus when dissolved in water; lubricates the oral cavity & hydrates food.
            - The digestive *enzyme* **salivary amylase** begins the hydrolysis of **starch** into **_____.**
    - Salivation is activated by:
        - food entering mouth
        - parasympathetic division of the ANS (chemoreceptors and mechanicoreceptors)
        - sight or smell of food
        - nausea, bacterial toxins in the GI tract, spicy foods, hyperacidity

PHYSIOLOGY: 3 main functions of the mouth

1. **Ingestion** of food.
2. **Mechanical Digestion**: the physical breakdown of food by **mastication** (chewing). The teeth break down the food while the tongue mixes the food with saliva to form a food **bolus**.
3. **Chemical Digestion**: salivary amylase hydrolyzes (breaks down) starches into glucose molecules (takes 15-30 minutes for completion). Starch break down is inactivated by the acids in the stomach.

Chapter 22: Digestive System, Continued

PHARYNX

ANATOMY

Structure of the pharynx: 2 regions important to digestive system

- Oropharynx: food passes into this area posterior to the mouth
- Laryngopharynx: this area, continuous the larynx, routes food and air into the proper channels

Two muscularis externa layers aid in peristalsis in the pharynx

PHYSIOLOGY

Function: propels food along to the esophagus

Deglutition: swallowing a bolus of food; has 2 phases

1. **Buccal phase**: it's voluntary and occurs in the mouth once food has been chewed and passed into the pharynx (swallowing). Swallowing is initiated once the tongue presses against the hard palate. Once food is pushes into the oropharynx, it is out of our voluntary control.
2. **Pharyngeal-esophageal phase:** this phase is involuntary. This process transports food through pharynx and esophagus. Food is kept out of the respiratory passages by the epiglottis. When the epiglottis covers the trachea, food slides into the esophagus (breathing stops temporarily). Food is squeezed into the stomach by peristalsis (solids take 4-8 seconds while liquids take 1-2 seconds).

ESOPHAGUS

ANATOMY

Structure: a 10 " gullet that runs from the pharynx through the diaphragm to the stomach; this muscular tube is found posterior to the trachea. The esophagus passes through the diaphragm at an opening called the **esophageal hiatus**. There's no serosa on the esophagus like the digestive organs sitting inferior to the diaphragm.

PHYSIOLOGY

Function: to propel food along from the mouth to the stomach. The esophagus has **NO digestive and NO absorptive roles** other than to propel food along via peristalsis.

STOMACH

ANATOMY: J-shaped organ found between the esophagus and small intestine, found inferiorly to the diaphragm. An empty stomach has a volume of 50 mL while a really full stomach can hold 4 L (1 gallon).

4 Regions of the Stomach

1. **Cardia**: named for close proximity to the heart; this region surrounds the area where food enters the stomach from the esophagus. Glands here secrete mucus to protect the stomach from its own acids.
2. **Fundus**: dome-shaped part under the diaphragm; superior to the esophagus-stomach junction
3. **Body**: midportion. Glands here secrete the acid and enzymes involved in digestion.
4. **Pylorus**: J-shaped part of the pouch; continuous with the duodenum of SI. Glands here secrete mucus, hormones, and gastrin (hormone that stimulates gastric glands of the stomach).

Chapter 22: Digestive System, Continued

STOMACH

ANATOMY, Continued

Sphincters are thickened areas of muscle (muscularis externa)

- **Cardiac (lower esophageal) sphincter**: valve found between the esophagus and the stomach.
- **Pyloric sphincter**: valve found between the stomach and the small intestine

Other features:

- **Rugae**: the mucosal lining (folds) of the stomach that appears when the stomach is empty.

Microscopic Structures and Secretions

- **Enteroendocrine cells** release at least 7 hormones, including **gastrin**. The vagus nerve, during parasympathetic control, promotes the release of gastrin. Gastrin is secreted by the stomach to stimulate the production of hydrochloric acid (HCl) and intrinsic factor. Acid activates pepsinogen into pepsin. **Gastrin-inhibiting peptide (GIP),** produced by the SI, inhibits gastrin production when stomach emptying occurs.
- **Parietal cells** release:
  - **HCl** makes the stomach pH acidic (pH = 1, 2); this acid activates pepsinogen to transform into pepsin (to hydrolyze (break down) proteins).
  - **Intrinsic factor** is a glycoprotein required for vitamin B_{12} absorption in the SI.
    - *Do you remember why **vitamin B_{12}** is important?*_____
    - *What type of anemia results when B_{12} is deficient?*_____
- **Chief cells** produce **pepsinogen** (the inactive form of the protein-digesting enzyme *pepsin*). In acidic conditions, pepsinogen is converted into pepsin. Pepsin hydrolyzes proteins.
- **Mucous neck cells** secretes acidic mucus which protects the stomach from digesting itself
- **Rennin** is produced by the stomach to break down milk proteins
- Cells in the fundus produce **ghrelin**, the hormone responsible for stimulating appetite and hunger

In Summary:

Vagus nerve stimulation triggers the release of:

↓

_____(Hormone)

which stimulates parietal cells to release:

↙ ↘

_____ and _____

Creates an acidic environment in the stomach, necessary for the conversion of _____ into _____.

Needed for the absorption of vitamin _____ and the manufacturing of new RBCs

PHYSIOLOGY

Summary of activities

1. **Mechanical digestion** mostly occurs here by peristalsis
2. **Chemical digestion** of protein and milk proteins
3. Very little absorption (only _____ and _____)

Chapter 22: Digestive System, Continued

STOMACH

PHYSIOLOGY, Continued

Regulation of Gastric Secretion

Gastric secretion is controlled by both neural and hormonal regulations

- *Nervous control* is provided by the **vagus nerve** (CN X) and local nerve reflexes
- *Hormonal control* is largely provided by **gastrin**

- **Phase 1: Cephalic Reflex (head)**
  - Occurs *before* food enters the stomach. Stomach prepares due to smell, sight, taste, or thought of food
  - *What happens?* _____ nerve **stimulates** stomach glands through a parasympathetic pathway
  - Depression or lack of appetite suppresses this reflex.
- **Phase 2: Gastric (stomach)**
  - Occurs when food is *in* the stomach. Two influences play a role in **stimulating** stomach gland secretion:
    - Stomach stretch receptors initiate reflexes to increase the output of gastric juices.
    - Alkaline pH environment or proteins or caffeine enter the stomach… in turn…

      --Gastrin is produced to increase acid content of stomach (HCl produced by parietal cells).

      --Gastrin activates pepsinogen to turn into pepsin.
- **Phase 3: Intestinal**
  - Occurs when food *enters* the duodenum of the small intestine
  - Excitatory portion causes the stomach to continue its activities.
  - Inhibitory portion (**enterogastric reflex**) causes the pyloric sphincter to tighten and prevent more food from entering the small intestine. So, stomach activity is inhibited.

    --**Gastrin inhibitory peptide** (**GIP**), a hormone produced by the small intestine, inhibits the stomach.

    --**Cholecystokinin (CCK)**, made by the duodenum, also slows the stomach's activities
  - **GOAL** = inhibit and slow the stomach activities and the emptying of contents from stomach to SI

Gastric Motility and Emptying

- The pyloric region of the stomach allows small amounts of chyme into the small intestine. Peristalsis squirts about 3 mL of chyme into the small intestine at a time.
- The stomach usually empties within about _____ hours of a meal.
- Stomach emptying depends on 1) duodenum, 2) stomach activities and 3) type of meal
- *What types of meals will slow the emptying of the stomach?*_____

STOMACH DISORDERS

- **Gastritis** = inflammation of the stomach wall due to a breach in the mucosa. BRAT diet is often prescribed (bananas, rice, applesauce, toast)
- **Gastric ulcers** = damage occurs to the underlying tissues of the stomach
- ***Helicobacter pylori*** = bacteria that often causes ulcers
- **Vomiting** (emesis) = leads to loss of HCl and metabolic alkalosis

Chapter 22: Digestive System, Continued

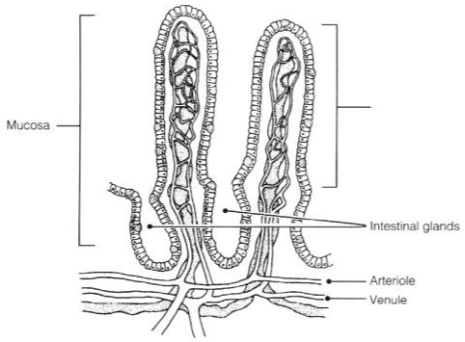
SMALL INTESTINE

ANATOMY

Three regions

1. **Duodenum**: first portion (10" long). Connects to the stomach at the pyloric sphincter. The duodenum also has an opening for dumping of bile and pancreatic juice called the (hepatopancreatic sphincter).
2. **Jejunum**: middle portion (8 feet). The majority of chemical digestion and absorption occurs here. The proximal end of the jejunum has prominent villi and circular folds for absorption.
3. **Ileum**: last portion (12 feet). Connects to the large intestine at the **ileocecal valve** (sphincter). This region has the *least* modifications for absorption; the distal end lacks circular folds, but Peyer's patches are found here to protect the small intestine from the bacteria normally living in the large intestine.

Three modifications to ↑ surface area and ↑ absorption:



1. **Villus** (*pl.* villi) are fingerlike projections of the mucosa which absorb food through the mucosal cells into the capillaries and the lacteals (modified lymphatic capillary). These structural modifications increase surface area for absorption.
2. **Microvillus** (*pl.* microvilli) are tiny projections of the plasma membrane of mucosa cells (villi). Microvilli often give the small intestine a fuzzy appearance called the brush border. Enzymes that hang out here are called brush border enzymes.
3. **Circular folds** (*plicae circulares)* are folds of the mucosa and submucosa which slows the movement of chyme (more time for absorption). Think of them as "speed bumps."

Intestinal Juice

- 1-2 L of intestinal juice are produced in response to stretching of the SI walls.
- Characteristics: pH 7.4 – 7.8; isotonic to blood plasma; mostly water and some mucous

PHYSIOLOGY

Summary of activities: Food spends 3-6 hours in this organ.

1. **Motility (Mechanical Digestion) of the Small Intestine**

   Segmentation: chyme is moved backward and forward (washing machine motion) to mix chyme with bile, pancreatic, and intestinal juices containing enzymes. This action ONLY occurs in the small intestine.

   Peristalsis also occurs to propel chyme toward the ileocecal valve in response to the hormone gastrin.

2. **Chemical digestion of all food groups is completed in the small intestine**
   - **Fats** are emulsified by **bile**. Bile emulsifies large fat globs into small droplets of fat (called micelles).
   - **ALL** food groups are hydrolyzed by **pancreatic enzymes** and **brush border enzymes**, made by the small intestine, aid with carb/protein hydrolysis.
3. **Absorption of all food groups, some water, and electrolytes occurs in the small intestine**

Chapter 22: Digestive System, Continued

SMALL INTESTINE

PHYSIOLOGY, Continued

Absorption

- Most nutrients, such as lipids and fats, are absorbed by active transport (requires ATP to move substances against the concentration gradient into the cell)
- Once nutrients travel across the mucosal layer into the villi, they enter the capillaries and lacteals in the villi and are carried to the liver by blood and lymphatic fluids.
- By the time chyme is pushed into the large intestine, it is nutrient poor (some 3-6 hours later).

Specific Nutrient Digestion and Absorption

- **Carbohydrates**
  - Chemical and mechanical digestion begins in the mouth
    - Salivary amylase
  - Chemical digestion (hydrolysis) is completed in small intestine using:
    - Pancreatic amylase
    - Small intestine enzymes such as maltase
- **Proteins**
  - Chemical digestion (hydrolysis) begins in the stomach by peptidases and proteases
    - Pepsin
    - Rennin
  - Chemical digestion (hydrolysis) is completed in small intestine with enzymes
    - Trypsin & chymotrypsin (produced by the pancreas)
    - Peptidases (produced by the small intestine)
- **Lipids**
  - Chemical digestion (hydrolysis) begins in the mouth
    - Small amounts of lipase
  - Chemical digestion (hydrolysis) is completed in small intestine
    - Bile (an emulsifier) breaks large globs of fat into smaller ones
    - Lipase (an enzyme) hydrolyzes lipids into fatty acids + glycerol
- **Nucleic Acids**
  - Chemical digestion (hydrolysis) begins and is completed in the small intestine by nucleases (produced by the pancreas)
- **Vitamins**
  - A, D, E, K are fat-soluble
  - B, C are water-soluble

Chapter 22: Digestive System, Continued

SMALL INTESTINE

PHYSIOLOGY, Continued

Specific Nutrient Digestion and Absorption, continued

- **Electrolytes**
  - Come from ingested foods and GI secretions
  - Most electrolytes are actively absorbed in the SI regardless if the body needs them or not.
  - **Iron** and **calcium** are absorbed in the duodenum *if* the body needs them. Calcium absorption is regulated by vitamin D and PTH.
  - **Sodium** absorption is coupled with the active absorption of glucose and amino acids. Sodium is actively pumped out of cells by the sodium-potassium pump.
  - **Potassium** ions are passively absorbed by facilitated diffusion in response to changing osmotic pressure. Anything that interferes with water absorption reduces potassium absorption, but also pulls more potassium from the interstitial space.
- **Water**
  - Of the 10 L of food and drink that reaches the large intestine, 9 L of water are absorbed in the small intestine by osmosis (about 300 to 400 mL per hour).
  - Water uptake is coupled with solute uptake (sodium, glucose, amino acids).

LARGE INTESTINE (COLON)

ANATOMY

- larger in diameter than small intestine, but shorter in length at 5 feet
- has three special features not seen anywhere else in the digestive system: teniae coli, haustra, epiploic appendages

Three Regions:

1. **Cecum**: 1st portion found on the right side of the body. Connects to the small intestine via the ileocecal sphincter/valve. The cecum has this subdivision:
   - **Appendix**: small appendage found hanging from the cecum on the right side of the body. Plays a role in immunity (part of MALT system – *see lymphatic system*).
2. **Colon** has these four subdivisions:
   - **Ascending colon** travels up right side, makes a right angle turn called the right colic (hepatic) flexure.
   - **Transverse colon** travels across the abdominal cavity, makes a left turn at the left colic (splenic) flexure.
   - **Descending colon** travels down the left side
   - **Sigmoid colon** turns, enters the pelvis, and joins the rectum.

Chapter 22: Digestive System, Continued

LARGE INTESTINE (COLON)

ANATOMY, Continued

3. **Rectum** is the last portion of the colon; the rectum has *rectal valves* to prevent feces from being passed out of the body along with gas.
    - **Anal canal** opens to the exterior; has an *external voluntary anal sphincter* and an *involuntary internal sphincter*. The internal sphincter is made of smooth muscle; it detects pressure from fecal matter and opens. The voluntary, external sphincter is consciously controlled since it's made of skeletal muscle. If the outer sphincter is not consciously opened when feces are present in the rectum, after a few seconds the internal sphincter detects the message and closes.

PHYSIOLOGY

Functions of the Large Intestine

- **Absorption**: Food products spend 12-24 hours in the large intestine for water and vitamins to be absorbed. There are no enzymes to break down nutrients, but mucus is secreted to lubricate the passage of feces.
- **Bacteria** (called *flora*) live there, release about 500 mL of gases each day, and metabolize some of the remaining nutrients into vitamins (B12 & K …*burger king*)
- **Produces feces** (contains water, mucus, bacteria, undigested food such as cellulose, bile pigments and salts, and epithelial cells).
- **Defecation:** elimination of indigestible substances from the anus as feces via the defecation reflex.

Motility in the Large Intestine

- **Haustral contractions:** slow movements that last about 1 minute; occur every 30 minutes or so. Function: _____
- **Mass movements**: long, slow-moving contractive waves that move over large areas of the colon 3-4 times a day. Function:_____
- **Defection reflex** is a parasympathetic reflex that causes the sigmoid colon and rectum to contract. Function is to push out feces. Defecation is initiated when feces stretch the sigmoid colon/rectum.

LARGE INTESTINE DISORDERS:

- **Diarrhea**: results from any condition that rushes food residue through the large intestine before that organ has had time to sufficiently absorb the water. The result is a watery stool. Causes include bacteria. Prolonged diarrhea can cause dehydration.
- **Constipation**: results from a lack of water in the stool. Causes may include lack of fiber.
- **Diverticulitis**: small herniations of mucosa through the walls caused by ↑ pressure within the colon.
- **Irritable bowel syndrome**: Abdominal pain accompanied by bloating, gas, nausea, depression. Stress is a common factor that causes IBS.

Chapter 22: Digestive System, Continued

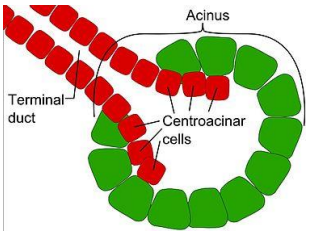
ACCESSORY DIGESTIVE ORGANS

PANCREAS

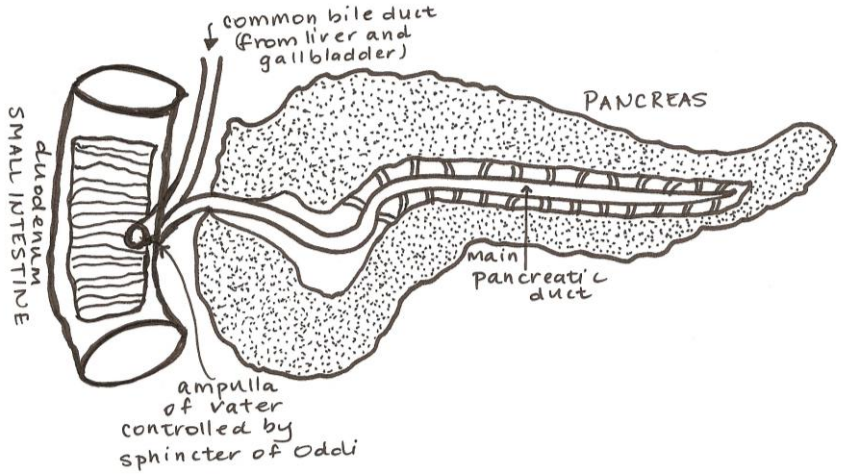
ANATOMY

Structure: triangular shaped heterocrine (endocrine + exocrine) gland found posterior to the stomach.

Two types of pancreatic cells:



- **Acini** are clusters of secretory cells that surround a duct; acinar cells produce enzyme-rich pancreatic juice. However, the epithelial cells lining the ducts, called ductal cells, release bicarbonate-rich pancreatic juice.
    - P**ancreatic juice** is secreted from the **main pancreatic duct**. The main pancreatic duct fuses with the **common bile duct** and enters the duodenum at the **hepatopancreatic ampulla**. The **hepatopancreatic sphincter** regulates the passage of fluids into the duodenum.
- **Pancreatic islets** (islets of Langerhans) are scattered among the acini. *Do you remember the two hormones the islets secrete?* _____



Pancreas and Duodenum Relationship

PHYSIOLOGY

Function: The pancreas produces two types of fluids:

1. **Enzyme-rich pancreatic juice** aids in the digestion of **ALL** food groups. It is triggered to be released from the pancreas when fats and proteins are in the small intestine.
    - **Pancreatic amylase** is an enzyme that completes the hydrolysis of starch into _____
    - **Pancreatic lipase** is an enzyme that hydrolyzes fats into _____ and _____
    - **Trypsin** and **chymotrypsin** complete the breakdown of proteins into amino acids.

2. **Bicarbonate-rich pancreatic juice** (pH = 8.4) is produced in response to secretin. This juice neutralizes acidic stomach chyme; raises pH in the small intestine closer to 7. *Why is it important for chyme in the small intestine to be nearer 7?* _____

_____

Chapter 22: Digestive System, Continued

PANCREAS

PHYSIOLOGY, Continued

Regulation of pancreatic juice

1. **Secretin**:

   --is released by the duodenum of the small intestine

   --is released in response to the presence of HCl (acid!) coming from the chyme from the stomach

   --travels via the blood stream to its target organs which are:

   --1) the pancreas. Secretin promotes the release of **bicarbonate-rich** pancreatic juice

   --2) the liver. Secretin promotes the release **bile.**

2. **Cholecystokinin** (CCK):

   --is released by the duodenum of the small intestine (not a hormone, but works over a neural circuit)

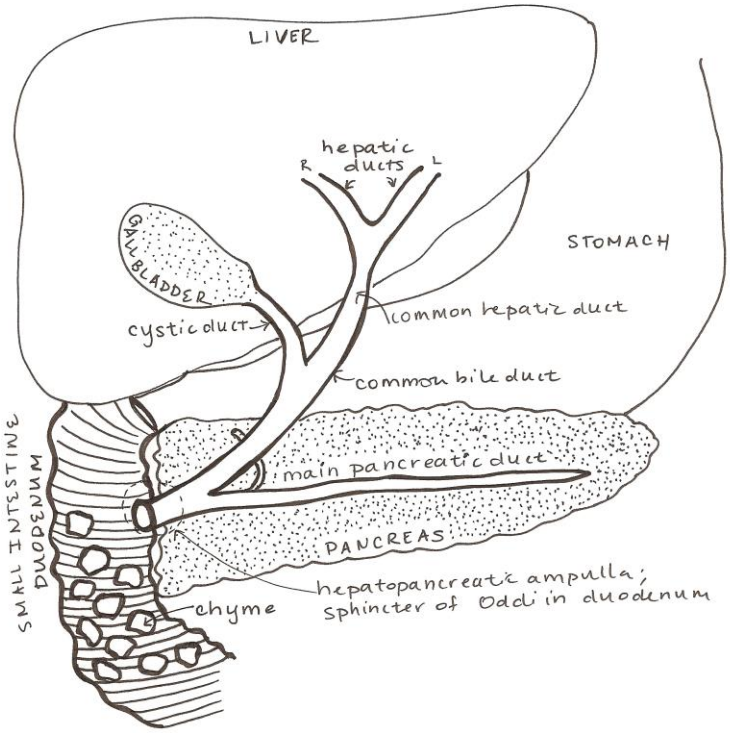
   --is released in response to the entry of fats and proteins coming from the stomach

   --travels via the blood stream to its target organs which are:

   --1) the pancreas. CCK promotes the release of **enzyme-rich** pancreatic juice

   --2) the gallbladder. CCK causes the gallbladder to contract and release **bile**

① Entry of acidic and/or fatty food into the duodenum triggers the release of CCK and secretin from the small intestine



② Secretin triggers the release of bile from the liver and bicarbonate-rich pancreatic juice from the pancreas.

CCK stimulates the gallbladder to release bile and the pancreas to release enzyme-rich pancreatic juice.

For Discussion:

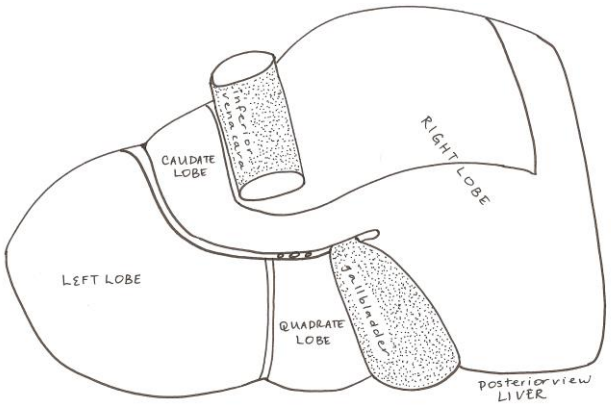
1. Explain what stimulates the release of CCK and secretin from the small intestine.
2. Describe the role pancreatic juice plays in chemical digestion.
3. What is the main function of amylase? Name two glands that secrete amylase.
4. Explain what happens to a piece of fat, steak, then bread as it passes from one organ to the next. Start with the mouth and end with the large intestine, include the types of chemical and mechanical digestion that affect each food.

Chapter 22: Digestive System, Continued

LIVER

ANATOMY

Structure: almost completely covers the stomach; oriented toward R side of the abdomen below diaphragm.



- Has 4 lobes: right, left, caudate and quadrate
- A mesentery (part of serous membrane), called the **falciform ligament**, separates the R and L lobes.
- Hepatic artery and hepatic portal vein both enter the liver together on the inferior side. The hepatic vein leaves the liver on the superior side on its way to the IVC.
- **Liver lobules** contain hepatocytes; they are the functional units of the liver situated around a central vein.

HEPATIC PORTAL CIRCULATION

This pathway is a detour; absorbed nutrients travel through liver before returning to heart.

① capillary of a villus
② superior mesenteric vein
③ hepatic portal vein
④ sinusoids of the liver
⑤ central vein
⑥ hepatic vein
⑦ inferior vena cava
⑧ right atrium of heart.

PHYSIOLOGY

Functions

- **Liver's role in the digestive system is to produce bile.**
  - Bile is a yellow-green fluid that lacks enzymes, but does contain:
    - **Bile pigments**
    - **Bile salts**, **phospholipids** (*only these chemicals help in digestion of fats)*
    - **Cholesterol, triglycerides, electrolytes**
  - Bile's job is to act as a fat emulsifier in the small intestine.
  - Bile leaves the liver via the common hepatic duct. It joins with the cystic duct coming from the gallbladder to form the common bile duct.
  - Secretin stimulates the liver to secrete bile.

Chapter 22: Digestive System, Continued

LIVER, continued

- **Other non-digestive liver functions include**:
  - Storage of glucose as glycogen (driven by insulin) and storage of fat-soluble vitamins
  - Use amino acids to make plasma proteins such as albumin to maintain BOP (blood osmotic pressure)
  - Detoxification of substances like ammonia, alcohol, drugs, lactic acid
  - Breakdown of **bilirubin** (chief bile pigment). Bilirubin is a waste product of heme (hemoglobin) formed when RBC are broken down. Globin and iron from hemoglobin are recycled, but bilirubin is made into bile by the liver cells. Bilirubin is broken into stercobilin by bacteria in the SI…make feces brown.

LIVER DISORDERS

- **Hepatitis** inflammation of the liver (often viral, but can be caused by bacteria, parasites, drugs, alcohol, autoimmune problems)
- **Cirrhosis** is progressive, chronic inflammation resulting from chronic alcoholism or severe chronic hepatitis. The liver becomes fatty and fibrous as the liver tries to regenerate and heal itself quickly. As scar tissue shrinks, the flow of blood is obstructed through the liver.
- **Jaundice** is the result of a buildup of bilirubin (blocks ducts, liver disease)

GALLBLADDER

ANATOMY

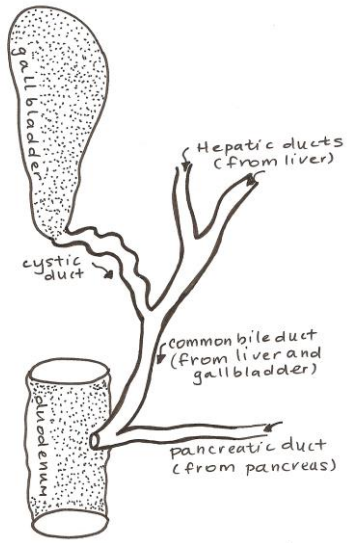
Structure: 4" long green sac that sits in a shallow hole in the ventral surface of the liver in the _____ lobe.

PHYSIOLOGY

Function: stores bile and releases it into the small intestine for digestion

How is bile stored in the gallbladder?

- Bile is concentrated & dehydrated, and backs up the _____ duct into the gallbladder for storage from the liver.
- Bile is concentrated and stored in the gallbladder



What happens when fatty chyme enters the small intestine?

- **CCK** is released by the duodenum. CCK travels by blood to the gallbladder.
- The gallbladder contracts and ejects the bile into the small intestine
- Hepatopancreatic ampulla is relaxed and open so bile and pancreatic juice can enter the duodenum

GALLBLADDER DISORDERS

- **Gallstones** (biliary calculi) occur with too much cholesterol or too few bile salts. The cholesterol in bile crystallizes, forming these stones. Each time the gallbladder contracts to eject its bile, the sharp crystals can cause pain. Since bile salts and pigments cannot enter the intestine, a person may become jaundiced.

Chapter 22: Digestive System, Continued

For Discussion

1. Compare the process of mechanical digestion to the process of chemical digestion.
2. Describe the role of digestive juices and hormones in fat and protein digestion.
3. Explain how the small and large intestines are different in structure.
4. Describe the role of the stomach in the digestive system.
5. Explain the role of sphincters (valves) in the digestive system.
6. What purpose does the esophagus serve?
7. Why does the large intestine have haustra? What purpose do they serve?
8. Describe the process of peristalsis. Which layer of the digestive tract aids in this process?
9. Name the organ where aspirin and alcohol are absorbed. Do you know which organ detoxifies these substances?
10. Explain how the production of HCl is regulated in the stomach.
11. Identify the locations of the salivary glands and explain their role in the process of chemical digestion.
12. Explain the purpose of villi, microvilli, and circular folds in the small intestine.
13. In what organ does segmentation occur? And what does segmentation accomplish?
14. Describe the role of the gallbladder and liver in fat digestion.
15. Trace the pathway of bile as it is released from the liver to the small intestine; list the pathway as it backs up for storage in the gall bladder.
16. Into which organ is bile secreted? Pancreatic juice? Rennin? Gastrin?

_____17. Completion of fat digestion is accomplished by:
- A. bile
- B. rennin
- C. amylase
- D. pepsin
- E. intrinsic factor

_____18. Breakdown of starch begins in the ____.
- A. mouth
- B. stomach
- C. esophagus
- D. small intestine
- E. large intestine

_____19. The absorption of vitamin ____ requires the presence of intrinsic factor.
- A. A
- B. B_{12}
- C. K
- D. D
- E. C

_____20. Peristalsis is performed by the:
- A. mucosa layer
- B. submucosa layer
- C. muscularis externa layers
- D. serosa layer
- E. mesentery

_____21. Mass movements occur in the:
- A. stomach
- B. esophagus
- C. large intestine
- D. liver
- E. small intestine

Answers: 17A, 18A, 19B, 20C, 21C

Chapter 23: Metabolism

Metabolism is the sum total of all the chemical reactions that occur in the body, and is controlled by specific catalysts called **enzymes.**

A. **Anabolism (Dehydration Synthesis)**: The chemical reactions that result in the formation of a larger, more complex molecule (called a polymer). Requires the input of energy. Water is removed from monomers to BUILD polymers.

- **Examples include**: protein synthesis on ribosomes (synthesis of actin, myosin, hemoglobin, antibodies), storage of fat, formation of scar tissue, conversion of glucose to glycogen.

B. **Catabolism (Hydrolysis)**: The chemical reactions that result in the breaking down of large molecules (polymers) into smaller ones (monomers) using enzymes. Energy is released while water is used. Water is split (hydrolysis) and added to BREAK DOWN and stabilize the newly formed monomers.

- **Examples include**: breaking down of glycogen into glucose, and complete catabolism of glucose (Glycolysis, Krebs cycle, Electron transport system); hydrolysis of proteins and fats

Chapter 23: Metabolism, Continued

CARBOHYDRATE METABOLISM

Foods include pasta, breads, potatoes, rice, starches, cellulose (found in green, leafy plants), sugars.

Carbohydrates are classified into different categories based on the number of sugar molecules:

- **Monosaccharide** = glucose, fructose, galactose
- **Dissacharide** = maltose, sucrose, lactose
- **Polysaccharide** = glycogen, starch, cellulose

GLUCOSE

CATABOLISM occurs during cellular respiration:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 34\text{-}36\ ATP$$

glucose + oxygen *yields* carbon dioxide + water + 34-36 ATP molecules

The purpose of cellular respiration is to convert glucose (food) and oxygen (air) into an energy molecule for the body, known as ATP. Cellular respiration occurs in & around mitochondria (eukaryotic organelle)

Anaerobic Cellular Respiration (Fermentation) pathway is similar to the Aerobic Cellular Respiration, except for oxygen is absent from this process. **Anaerobic =** *without oxygen.* Lactic acid is produced during anaerobic respiration.

ANABOLISM: Glucose molecules join to form glycogen during **glycogenesis** (driven by insulin)

GLYCOGEN can be broken down into glucose molecules during **glycogenolysis** (driven by glucagon)

FATS AND PROTEINS can be broken down into glucose molecules during **gluconeogenesis** (driven by cortisol).

For Discussion:

1. Trace the pathway of glucose from its absorption in the small intestine into the blood stream. Take the glucose molecule back to the right atrium of the heart.
2. What type of catabolic reaction is used by people who are dieting?
3. Differentiate between gluconeogenesis and glycogenolysis. What reactants does each reaction use? What produced is produced in each reaction?

Chapter 23: Metabolism, Continued

LIPID METABOLISM

Fatty foods include butter, oils, meats such as bacon, sausage, beef, and dairy products such as lard, cream.

The chief functions of fats: used to make cell membrane, steroid hormones, excess stored as adipose tissue, supplies energy.

Transport of Fats:

- **HDLs (high density lipoprotein)** carry cholesterol to the liver where it is broken down and becomes part of bile. These are the "helpful" lipoproteins and they should outnumber the LDLs.
- **LDLs (low density lipoprotein)** carry cholesterol to peripheral tissues where it can be used to make membranes or hormones (or stored for later use). These are the "lousy" lipoproteins and can thicken and stiffen blood vessel walls.
- **Atherosclerosis**: narrowing of arteries due to the accumulation of cholesterol + calcium (plaque). It starts by picking up LDL (low density lipoproteins) and then accumulates fibrous tissue and platelets. The end stage is **arteriosclerosis** which is hardening of the arteries due to loss of elasticity and deposits. Thrombi can form and completely block the vessel.

FAT CATABOLISM

- Lipids (fats) break down into their monomers (building blocks) called fatty acids[1] and glycerol[2].
  (1) This fatty acid can be converted to acetyl coenzyme A (acetyl CoA)
  (2) This glycerol can be converted to glucose, a process called **gluconeogenesis**.
- **Beta oxidation** is the process by which fatty acids are broken down into acetyl coenzyme A (acetyl Co A)
- **Ketosis**. Condition which results when **fatty acids** (*not* proteins) are incompletely (abnormally) metabolized. Excessive amounts of acetyl coA are formed. Liver will combine acetyl coA and form ketone bodies. People who are diabetics (mellitus), starving, or dieting may experience *ketoacidosis*, a condition in which the blood pH becomes acidic due to these ketones. Ketoacidosis is classified as metabolic acidosis. How would the respiratory rate change in compensation? _____

For Discussion:

1. Why do diabetics check their urine for ketone bodies? Likewise, why do dieters check their urine for ketone bodies?
2. Why does the ratio of HDL to LDL matter?
3. Why is it better to have more HDL than LDL? What are the roles of HDL and LDL?
4. Why could a person with a liver disorder have fatty streaks in the stool?

Chapter 23: Metabolism, Continued

PROTEIN METABOLISM

Foods include skinless poultry, fish, lean beef, lean pork, legumes, soybeans, corn, tofu.

Proteins are broken down into their monomers or building blocks amino acids. There are a total of **20** amino acids. Of the 20 amino acids, 8 are called **essential** meaning you need to consume these in your diet, your body does not make them.

PROTEIN SYNTHESIS (Protein Anabolism): Proteins are made on ribosomes during protein synthesis using amino acids as the building blocks. The major function of proteins is for growth and replacement of body tissue. Examples of some proteins made during protein synthesis are: actin, myosin, hemoglobin, antibodies, keratin, enzymes.

PROTEIN CATABOLISM: Proteins are broken down into amino acids. In the liver, the hepatic cells remove NH_3 from an amino acid and produce urea and keto acids. This process is called **deamination**. The urea that is formed will be taken to the kidney and will exit in the urine. The keto acid that is formed can be converted to acetyl Co A; or it can be converted to glucose, a process known as gluconeogeneisis. **Note** that acetyl CoA resulting from fatty acid breakdown cannot be used for gluconeogenesis because the metabolic pathway is irreversible past pyruvic acid.

Metabolic syndrome

Symptoms

1. abdominal (central) obesity
2. elevated blood pressure
3. elevated fasting blood glucose
4. high blood serum triglycerides
5. low high-density lipoprotein (HDL) levels

Risk for the development of:

1. _____
2. _____

For Discussion:

1. How can protein eventually turn into glucose? What is the name of this transformation?
2. What role does deamination play in breaking down proteins?
3. How does ketoacidosis affect the blood pH?
4. Where does protein digestion begin in the digestive tract? And where is protein digestion completed?
5. What happens during ketosis? What are ketone bodies?

Chapter 23: Metabolism, Continued

VITAMINS

Vitamins are not made by the body *except* for B, D, and K. B and K are made by the enteric bacteria and D is made by the skin in the presence of sunlight. All of the fat-soluble vitamins can be stored in the liver except for vitamin K.

- **Hypervitaminosis** can occur when fat-soluble vitamins accumulate and are stored in fatty tissues and the liver.
- **Avitaminosis** is rare since fat-soluble vitamins are stored. Avitaminosis is more likely to occur with a B or C vitamin since they are water soluble and only B_{12} and C are stored.

Fat Soluble Vitamins	Why do we need it?	Food sources	Deficiency:	Water Soluble Vitamins	Why do we need it?	Food sources	Deficiency:
A (beta carotene)	Vision (rods)		Night blindness	**B_1 (thiamine)**	Nervous system functions		Beriberi disease (muscle, skin, nervous system deterioration)
D		Dairy products	Rickets in children; osteomalacia in adults	**B_2 (riboflavin)**	Enzyme function, other vitamins		Cracked lips at corners of mouth; dermatitis
E	Immune functions; antioxidant		*Rare*	**B_3 (niacin)**		Meat, eggs, fruits, veggies, beer	Pellagra (4D = dermatitis, diarrhea, dementia, death)
K		Green leafy veggies	Bruising occurs more easily	**B_9 (folic acid)**		Whole grains, cereals	Spina bifida
				B_{12}		Animal protein (meat, eggs, milk)	Pernicious anemia
				C	Collagen synthesis		Scurvy (sailors)

For Discussion:

1. Which vitamins can be stored in the body?
2. Which category of vitamins should be not be overindulged in for fear of vitamin overdose?
3. Why might a person with anemia be advised to take vitamin B12 and folic acid?
4. Why do you think that sailors (especially in the past) might be at risk for vitamin C deficiencies.
5. What do alcoholics and those suffering from malnutrition share in common? Why would both of these conditions lead to pellagra?
6. A person with a fat-metabolism disorder, such as *abetalipoproteinemia*, would have problems absorbing which of these vitamins?
7. How would long-term use of antibiotics affect levels of vitamins B and K in the body?
8. Why should vitamins A, D, E, and K be taken with foods that contain some fat?

Chapter 23: Metabolism, Continued

Review of Nutrition & Metabolism

_____1. Glycerol is converted to glucose for use in cellular respiration in a process called:
A. glycolysis
B. gluconeogenesis
C. deamination
D. Beta oxidation
E. ketosis

_____2. Only vitamins ____ are made by the body; the rest must come from our diet.
A. K, B, E
B. K, D, E
C. B, K, D
D. A, C
E. C, K

_____3. Glycogenesis occurs when glucose is converted to glycogen under the direction of:
A. glucagon
B. insulin
C. glucocorticoids
D. mineralocorticoids
E. adrenaline

_____4. Protein catabolism produces ____ which is excreted in urine.
A. amino acids
B. urea
C. nucleic acids
D. glucose
E. glycerole

_____5. Which of these lipids transports cholesterol to the liver for breakdown and inclusion in bile?
A. LDL
B. chylomicron
C. HDL
D. testosterone
E. triglycerides

_____6. The purpose of cellular respiration is to convert ____ into ____.
A. glycerol…glucose
B. glucose…glycogen
C. glucose…ATP
D. glycerol…ATP
E. ATP…glucagon

Answers: 1B, 2C, 3B, 4B, 5C, 6C

Chapter 24: Urinary System

FUNCTIONS OF THE URINARY SYSTEM

1. Removal of wastes from the blood through the formation of urine.
2. Regulates the volume and composition of the blood.
3. Helps control the blood pH
4. Helps regulate blood pressure (production of renin).
5. Produces the hormone erythropoietin (EPO), which stimulates red blood cell production in the red bone marrow.

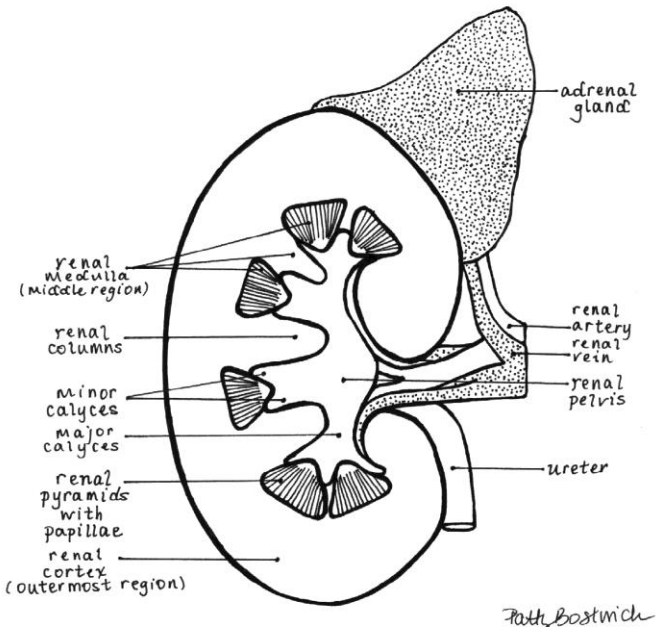
ANATOMY OF THE KIDNEYS

External Anatomy

1. About the size of a large bar of soap (12 cm long, 6 cm wide, 3 cm thick)
2. A medial indention is the **hilus** (where the ureters, renal blood vessels, & nerves enter)
3. **Adrenal gland** sits on top of the kidney
4. **Three layers of tissue surround the kidney**
   a. **Fibrous capsule** encloses each kidney and prevents the spread of infections
   b. **Perirenal fat capsule** surrounds the kidneys and is important in holding them in their normal position; also cushions against blows
   c. **Renal fascia** is dense fibrous CT that anchors the kidney and adrenal gland to surrounding structures

Internal Anatomy

1. **Three Regions**
   a. **Renal cortex** is the most superficial region; includes the renal columns.
   b. **Renal medulla** contains the **renal** or **medullary pyramids**. There are 8-18 of these triangular pyramids--each has an apex (papilla) that points toward the inside of the kidney.
   c. **Renal pelvis** is a flat, basinlike cavity medial to hilus; urine collects here before traveling down ureter.
2. **Calyces**: form cup-shaped areas that enclose tips of pyramid—where urine first drips from minor calyces. There are 2-3 **major calyces** that subdivide to form several **minor calyces** (areas that enclose the papillae of the pyramids).



FILTERED ITEMS THAT ARE NOT REABSORBED or SECRETED ITEMS BECOME URINE: Urine drips from the pyramid's renal papilla into a minor calyx → major calyx → renal pelvis → ureter → urinary bladder → urethra

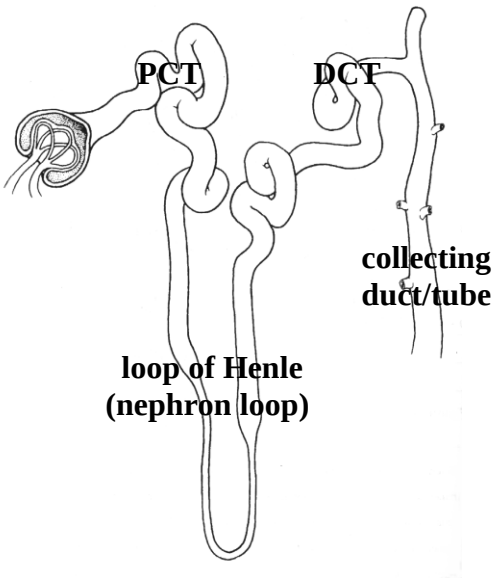
Chapter 24: Urinary System, Continued

NEPHRON ANATOMY

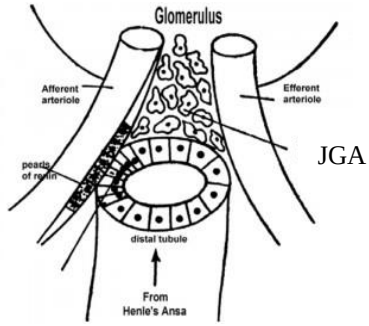
Millions of nephrons are contained in each kidney; their FUNCTION = filter the entire blood volume 60x/day! Nephrons are the **functional unit of the kidney.**

Two main portions of the nephron:

1. **Renal corpuscle** = Bowman's capsule and glomerulus
   a. **Glomerulus:** knot of capillaries that filter blood that operate under high hydrostatic pressure.
   b. **Glomerular (Bowman's) capsule:** the closed end of the renal tubule is this enlarged, cup-shaped structure that surrounds the glomerulus. This capsule captures filtrate.
2. **Renal tubule**: rest of tubule extends from glomerular capsule, and coils and twists to form a hairpin loop before entering a collecting tubule called the collecting duct. The renal tubule is simple cuboidal ET.
   a. **proximal convoluted tubule (PCT)** this coiled tube is closest to the Bowman's capsule
   b. **loop of Henle/nephron loop (ascending and descending limbs)** is a U shaped portion of the renal tubule
   c. **distal convoluted tubule (DCT)** this coiled portion is farthest from the Bowman's capsule
   d. **collecting duct** receives filtrate from the DCT of many nephrons. Urine is carried through papillary ducts which open at the renal papilla. Urine then drips into the minor calyces.



The **juxtaglomerular apparatus (JGA)** is located between the renal corpuscle and the DCT of the same nephron. It detects BP & regulates renal blood flow and glomerular filtration rate by releasing renin. Recall the renin angiotensin mechanism: renin → angiotensin I $\xrightarrow{ACE}$ angiotensin II → aldosterone & ADH.



Types of Nephrons

1. **Cortical nephrons** are located almost entirely in the renal cortex of the kidney. Cortical nephrons include 85% of all nephrons in the kidney; they produce dilute urine.
2. **Juxtamedullary nephrons** are located near the cortex-medulla junction. Their loops of Henle travel into the medulla of the kidney. Their loops of Henle have both thick and thin segments; they produce concentrated urine.

For Discussion:

1. A dehydrated patient has concentrated urine. Is ADH active or inactive? What type of nephron is active?
2. Trace a filtered substance from the renal pyramid through the nephron to the collecting duct.
3. Trace urine from the renal pyramid to the urethra.

Chapter 24: Urinary System, Continued

BLOOD SUPPLY TO & FROM THE NEPHRON

- **Renal artery** carries ¼ of the blood (approximately 1200 mL of blood) to the kidney during resting conditions each minute. As it enters the kidney, it branches into…
- **Segmental (lobar) arteries** (5). Each of these arteries divides into…
- **Interlobar arteries** which branch at the medulla-cortex junction into…
- **Arcuate arteries** that arch over the medullary pyramids and branch into…
- **Cortical radiate (interlobular) arteries** which supply the cortex tissue. These arteries give rise to…
- **Afferent arterioles** which feed the glomerulus with blood. These are high-pressure arterioles. Blood then travels through the…
- **Glomerulus (capillaries)** where filtration occurs. Since the efferent arteriole has a small diameter than the afferent arteriole, pressure is unusually high in the glomerulus—high for a capillary bed, that is. The high pressure promotes filtration. Blood leaving the glomerulus travels through the…
- **Efferent arterioles** which connect back to the venous supply. This is a rare example of an arteriole carrying blood back toward the heart, not a vein. The efferent arterioles form…
- **Peritubular capillaries** are porous. They wrap around the PCT, loop of Henle, and DCT and absorb solutes and water from the tubule cells. These capillaries join to form…*see below*
- **Venules**
- **Cortical radiate (interlobular) veins**
- **Arcuate veins**
- **Interlobar veins** (*Notice there are no segmental veins*)
- **Renal vein** which exits the kidney at the renal hilus

For Discussion – one or more of these four tracings may appear on Exam #4

1. Trace the pathway of a red blood cell from the renal artery, through the nephron, and back to the renal vein.
2. Trace the pathway of a creatinine that is secreted. Start with the renal artery and end with the creatinine leaving the body in urine.
3. Trace the pathway of a bicarbonate ion that is filtered and reabsorbed. Start with the renal artery, take the ion through filtration, then reabsorption in its proper location, and then back to the renal vein.
4. Trace the pathway of sodium ions that are filtered but not reabsorbed. Start with the renal artery, and end with the sodium ions leaving the body in urine.

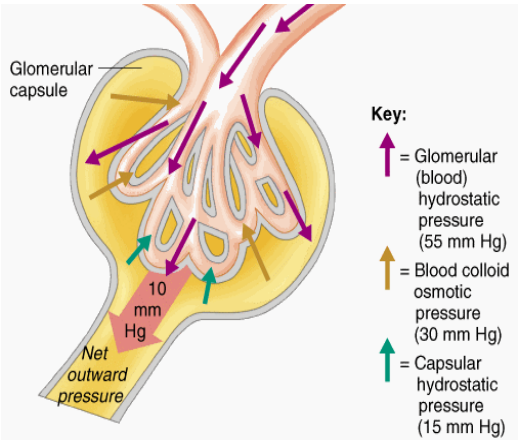
Chapter 24: Urinary System, Continued

Study closely! The next four pages are commonly missed on tests!

THREE MAIN ACTIVITIES OF THE NEPHRON
Filtration, Tubular Reabsorption, Tubular Secretion

FILTRATION (GLOMERULUS)

- *Where does this take place in the nephron?* glomerular capillaries – porous and under high pressure. Podocytes are cells forming the capillaries with feet-like extensions.
- *What's in the filtrate*: all the liquid in the blood plasma except for formed elements and proteins
- *What should **NOT** be in the filtrate?* items that are too large to pass out of the capillaries, such as the RBC, WBC, or blood proteins
- *Under what conditions will it form?* under normal BP
    - *BP too low?* Juxtaglomerular apparatus (JGA) cells produce renin. Renin leads to angiotensin I, then ACE transforms it to angiotensin II. Angiotensin II will constrict the efferent arteriole if blood pressure (hydrostatic pressure) drops too low so the process can continue. If BP is too low, filtrate formation stops and results in too little urine formation. Angiotensin II also promotes the formation of aldosterone & ADH to ↑ BP.
- **Net filtration pressure** (**NFP**) = 10 mm Hg. NFP is responsible for filtrate formation. There has to be more pressure pushing fluids out of the glomerulus than pressure letting fluids come back in the glomerulus.



- **Glomerular Filtration Rate (GFR)** = volume of filtrate formed by the kidneys each minute.
    - It is *directly proportional* to the NFP.
    - In adults, the GFR in both kidneys is 120 mL/min.
    - *How many liters of plasma are filtered each day?* 120 to 125 mL/min x 60 min/hr x 24 hr/day = 180 L/day. But, only about 1.5 L of urine are produced, about 99% of fluids are **reabsorbed**!
- **Renal clearance** is the volume of plasma from which a particular substance, such as creatinine or inulin, is completely removed (cleared) by the kidneys in a given time (usually a minute). This is a way to measure glomerular filtration rate (GFR), which provides information about renal functioning. Essentially, renal clearance compares the amount of substance X in the urine with the amount of substance X in the blood.

Chapter 24: Urinary System, Continued

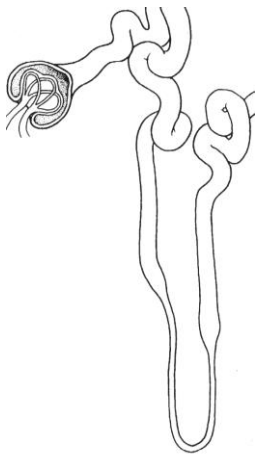
THREE MAIN ACTIVITIES OF THE NEPHRON, continued

TUBULAR REABSORPTION (PCT)

- *Where does this take place in the nephron?* Items move from the filtrate via reabsorption, usually at a fixed rate, back into the blood of the peritubular capillaries that surround the tubules of the nephron.
- *What's reabsorbed?* 99% of what has been filtered out as filtrate…reabsorbed items include water, salts, amino acids, nutrients like glucose, etc.
- **ONCE REABSORBED, how do these items return to the blood flow back to the renal vein?** from the PCT → peritubular capillaries → venule → cortical radiate vein → arcuate vein → interlobar vein → renal vein

Chemical Reabsorbed	Percentage Reabsorbed from Filtrate	Coupled with?	Hormone Involved?	Notes
Sodium	60-70%	--	No	
Glucose	100% (normally)	Sodium	No	Transport maximum of 180 mg/100 mL of plasma; glucose exceeding 180 is dumped into the urine and lost (glucosuria)
Chlorine	--	Sodium	No	We can lose hydrogen ions and chlorine ions through vomiting – sending us into *alkalosis*.
Bicarbonate (HCO_3^-)	--	Sodium	No	Reabsorbed ions help maintain blood pH (if blood pH is *acidic*)
Water	60-70%	Sodium	No	Obligatory water reabsorption means water is reabsorbed whether we need it or not
Amino Acids	100%	--	No	

TUBULAR REABSORPTION (Loop of Henle)



- **LOOP OF HENLE** is responsible for absorbing 50% water, 2/3 sodium and chloride ions remaining in the tubular filtrate.
- **COUNTERCURRENT MULTIPLICATION**: Exchanges occur to adjust the salinity (saltiness) of the filtrate. Function is to maintain solute concentration of the filtrate in the nephron loop.
    - **Water** is reabsorbed from the filtrate in the **descending limb** (but **not solutes**).
    - **Sodium** and **chlorine** are reabsorbed from the filtrate in the **ascending limb** into the blood (but **not water** since no aquaporins are present). *Lasix* inhibits sodium reabsorption (called a *loop diuretic*).

Chapter 24: Urinary System, Continued

THREE MAIN ACTIVITIES OF THE NEPHRON, continued

TUBULAR REABSORPTION (DCT)

- DCT is responsible for absorbing remaining items in the filtrate (such as water or ions). But, here, reabsorption is driven by the body's needs and regulated by hormones.
- **ONCE REABSORBED, how do these items return to the blood flow back to the renal vein?** from the DCT → peritubular capillaries → venule → cortical radiate vein → arcuate vein → interlobar vein → renal vein

Chemical Reabsorbed	Process	Hormone Involved?	Mechanism	Notes	Reabsorption Inhibited by:
Sodium	Facilitated Diffusion through **sodium channels**	Aldosterone	**Renin-Angiotensin Mechanism**: --BP and blood volume drop when sodium levels drop. --Renin, released by the kidney, converts angiotensin I to angiotensin II. --Angiotensin II constricts the efferent arteriole so filtrate still forms if BP has dropped. --Angiotensin II also promotes the release of aldosterone	If aldosterone is present and sodium is reabsorbed, potassium is secreted.	--Caffeine
Water	Osmosis; **aquaporin channels**	ADH Aldosterone	ADH inserts aquaporins for water reabsorption when osmotic pressure rises. Helps retain water to dilute down salty blood. Water passively follows sodium…	--Facultative water reabsorption in the DCT is performed under the presence of ADH. --Without ADH, dilute urine is formed. In the presence of ADH, concentrated urine is formed.	--Caffeine (diuretic) --Glucose (osmotic diuretic) --Alcohol (inhibits ADH)
Calcium	--	PTH Calcitriol	--	Reabsorbed to increase blood calcium levels	

Chapter 24: Urinary System, Continued

THREE MAIN ACTIVITIES OF THE NEPHRON, continued

TUBULAR SECRETION

- *Where does this take place in the nephron?* PCT, DCT or collecting duct/tube
- *What's secreted*? items that the body doesn't need that end up in urine
- *Purpose of secretion?* 1) Maintain proper blood pH (7.35 – 7.45) and 2) Rid the body of wastes not filtered during glomerular filtration. These items travel from the peritubular capillaries to PCT, DCT or CT.
- **ONCE SECRETED, where does the item go next?** from the peritubular capillaries→ DCT or collecting duct → renal papillae → minor calyces → major calyces → renal pelvis → ureter → urinary bladder → urethra

Chemical Secreted	Role in the Body	Hormone Involved?	Notes
Potassium	Major intracellular electrolyte	Aldosterone stimulates K+ secretion	--Potassium can be both filtered and secreted. --**Hypokalemia** can develop through insulin use (diabetes mellitus). --**Hyperkalemia** can cause cardiac arrhythmias. --DCT secretion
Hydrogen	Blood pH maintenance	Aldosterone stimulates H+ secretion	--If a person experiences **Respiratory Acidosis**: the compensation is to ↑ H+ ions secretion from blood into the urine while ↑ reabsorption of bicarbonate ions from filtrate into the blood. -- If a person experiences **Respiratory Alkalosis**: the compensation is to ↓ H+ ions secretion from blood into the urine. Likewise, ↓ reabsorption of bicarbonate ions from filtrate into the blood. --DCT and CT secretion
Urea	Waste product of protein metabolism	--	--Urea can be both filtered and secreted. Some is reabsorbed.
Uric acid	Waste product of RNA metabolism	--	--Uric acid can be both filtered and secreted. Some is reabsorbed.
Creatinine	Waste product of creatine phosphate production (muscles)	--	--Creatinine can be both filtered and secreted. Creatinine is used to calculate GFR since it is typically not reabsorbed.

Chapter 24: Urinary System, Continued

Review of Nephron Functions

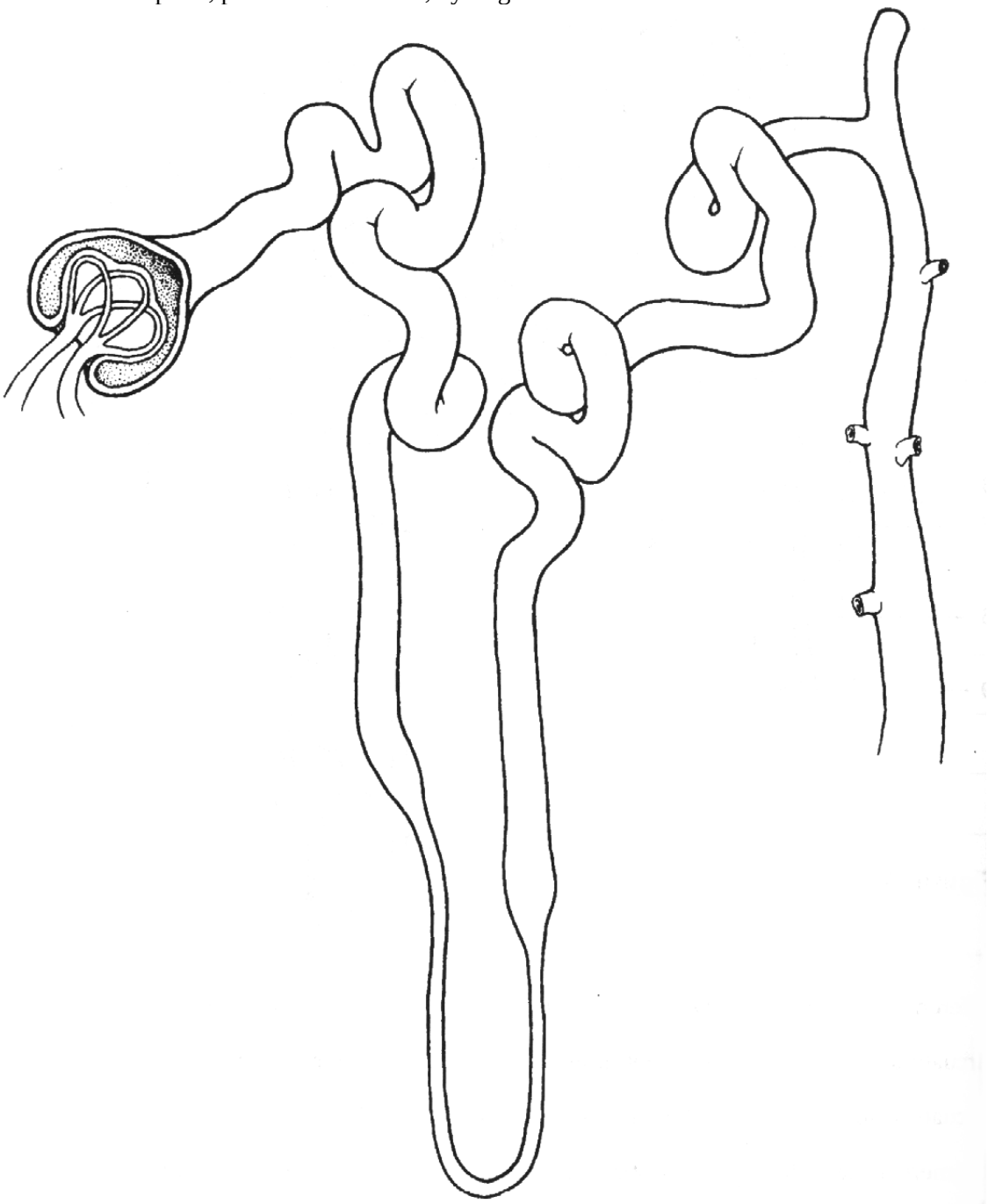
Complete this chart:

Substance	Filtered? If so, where?	Secreted? If so, where?	Reabsorbed? If so, where?	Type of transport?	Regulated by? (Hormone?)
Water					
Sodium					
Potassium					
Chlorine					
Hydrogen					
Bicarbonate					
Calcium					
Glucose					
Amino Acids					
Urea					

Chapter 24: Urinary System, Continued

Review of Nephron Function

1. **Label** the afferent and efferent arterioles, glomerulus, Bowman's capsule, PCT, loop of Henle, DCT, and collecting duct. **Draw** in the peritubular capillaries.
2. **Label** the locations of filtration, reabsorption, and secretion.
3. **Mark** on the nephron *where* the following activities occur: water reabsorption with and without presence of ADH, sodium reabsorption with and without presence of aldosterone, bicarbonate reabsorption, chlorine reabsorption, glucose reabsorption, calcium reabsorption, potassium secretion, hydrogen secretion.



Chapter 24: Urinary System, Continued

Read the following three pages as homework.

CHARACTERISTICS OF URINE

1. *These substances are commonly found in urine*: water & solutes (sodium, potassium, urea, uric acid, creatinine, ammonia, bicarbonate)
2. *These substances should **NOT** be found in urine*; they're listed below with what problems they indicate:
   - **glucose** indicates diabetes mellitus and is called *glycosuria*
   - **blood proteins** (like albumin) indicates that it was able to pass through the glomerulus and perhaps blood pressure is too high …called *proteinuria* or *albuminuria*
   - **red blood cells** indicate possible pathology of the urinary tract … called *hematuria*
   - **hemoglobin** indicates hemolytic anemia, transfusion reactions, burns, or renal disease … called *hemoglobinuria*
   - **white blood cells** indicate inflammation of the urinary tract …called *pyuria*
   - **bile** indicates a liver disorder …called *bilirubinuria*
3. **pH**
   - Normal pH = 4.5 – 8.0
   - Average pH value = 6.0 (slightly acidic)
   - pH value depends on diet and blood pH: high protein diets have low (acidic) urine pH while a diet consisting mainly of vegetables results in high (alkaline) urine pH
4. **Urine volume**
   - During a 24 hour period of time, 1.0 – 1.8 liters of urine can be produced
   - Factors that can influence urine volume
     - Blood pressure (renal BP decreases, urine output decreases)
     - Temperature (cold causes increased urine output)
     - Diuretics (caffeine and alcohol inhibit sodium reabsorption, leading to decreased water reabsorption, so urine output increases)
     - Emotions (increases BP, increases GFR, and increases urine output)
     - Blood Composition (dehydration leads to increased ADH and decreases urine output)

5. **Color of urine** is due to the amount of solutes in the urine. Certain substances can affect the color of urine—such as beets, asparagus, various drugs, bile, blood. The normal yellow color is due to *urochrome*, a pigment arising from the body's destruction of **hemoglobin** via urobilinogen**.** Cloudy urine may indicate urinary tract infection (UTI).
6. The amount of solutes dissolved in urine is called the **specific gravity**; closer to 1.001 indicates dilute urine while a value closer to 1.035 indicates concentrated urine.
7. **Odor of urine** is slightly aromatic; stale urine has an ammonia odor. Diabetic urine has a "fruity" odor due to the acetone content. Some drugs and vegetables may also alter odor (like asparagus).

Chapter 24: Urinary System, Continued

ANATOMY & PHYSIOLOGY OF THE URETERS, BLADDER, AND URETHRA

Ureters

- **Pathway of urine:** urine formed in the nephrons passes through the collecting ducts → papillary ducts → renal papillae → minor calyx → major calyx → renal pelvis → ureter
- These muscular tubes are 10 inches long, and become more slender in diameter they descend (enter superior lateral wall of bladder).
- **Three Tissue Layers of the Ureters**:
    - **Mucosa**: inner lining of mucus-secreting transitional epithelium. The mucus prevents the epithelium from being damaged by the acidic urine.
    - **Muscularis**: middle layer; has longitudinal and circular sheets of smooth muscle that function in peristalsis (triggered by stretch when urine enters ureters). **Peristalsis**: wavelike contractions of the smooth muscle in the ureter walls propels the urine towards the bladder (not gravity alone!)
    - **Adventitia**: outer layer of fibrous connective tissue that anchors the ureters in place in the abdominal cavity.
- **Function of Ureters**: transport urine from the kidney to the bladder occurs by peristalsis

Urinary Bladder

- A hollow, collapsible, muscular organ held in the pelvic cavity, just posterior to the pubic symphysis, by folds of the peritoneum.
- **Trigone**: smooth, triangular area at the base of the bladder, formed by three openings: 2 ureters (base of Δ) and 1 urethra (apex).
- **Three Tissue Layers in Bladder Wall**:
    - **Mucosa**: inner lining of mucus-secreting transitional epithelium
    - **Muscular layer** (Detrusor): 3 layers of smooth muscle in the middle
    - **Fibrous adventitia**: outer covering of fibrous connective tissue
- **Sphincters**: There are two of these circular bands of muscle at the base of the bladder.
    - **Internal urethral sphincter**: circular band of smooth muscle at bladder-urethra junction that prevents leakage of urine between voidings.
    - **External urethral sphincter**: circular band of skeletal muscle below the internal sphincter; you learn to consciously control it when you're "potty trained"!

Chapter 24: Urinary System, Continued

ANATOMY & PHYSIOLOGY OF THE URETERS, BLADDER, AND URETHRA

Urinary Bladder, continued

- **Micturition**: expelling urine from the bladder ("voiding")
    - During a 24 hour period, 1.5 L of urine is produced
    - When about 200 mL of urine accumulates in the bladder, distension of the walls triggers stretch receptors which send sensory impulses to the sacral spinal cord. The bladder holds around 500 mL (full).
    - Efferent impulses from the cord are sent over parasympathetic pelvic splanchnic nerves, (visceral reflex arc) causing the detrusor muscle to contract, and the internal urethral sphincter to relax (open).
    - Cerebral cortex: impulses reaching this cause the conscious desire to urinate. The cortex sends efferent motor impulses to the external urethral sphincter to make it relax and open; then urination can occur.
    - Although it is a reflex, it may be initiated voluntarily, and stopped at will because of cortical control of the external sphincter. However, the urge to void eventually becomes irresistible, and micturition occurs, whether one wills it or not!

Urethra

- Thin-walled, muscular tube extending from floor of bladder to exterior of body. About 1.5 inches long in females, and 8.0 inches long in males.
- Function: transport urine from bladder to the exterior of the body
- Because the female urethra is very short, and close to the anal opening, improper toilet habits (wiping back to front) can easily result in UTIs:
    - **urethritis**: inflammation of urethra
    - **cystitis**: inflammation of bladder
    - **pyelonephritis**: inflammation of entire kidney

Describe the following disorders (indicate cause, symptoms):

- glomerulonephritis (Bright's disease) - inflammation of the _____.
- diabetes insipidus – due to an insufficient level of the hormone _____.
- renal calculi (kidney stones)

Chapter 24: Urinary System, Continued

Review of the Urinary System

no answers provided here

1. Compare obligatory water reabsorption with facultative water reabsorption. Explain how and where each occurs.
2. Explain how pressure in the glomerulus pushes plasma fluids out to be filtered.
3. Explain how sodium reabsorption affects water reabsorption.
4. Discuss how alcohol increases urine output.
5. How does the secretion of hydrogen ions affect blood pH?
6. What happens to glucose in the filtrate that exceeds the transport maximum?
7. How is potassium secretion related to sodium reabsorption?
8. Why is GFR a good indicator of healthy kidney function?
9. When osmotic pressure of the blood (BOP) is high (water content is low), what happens next to restore proper blood volume?
10. Why does hyposecretion of ADH lead to large amounts of urine output?
11. Why does a low amount of sodium in the blood lead to aldosterone release? How does aldosterone "fix" this problem?
12. Compare the processes of sodium reabsorption in the PCT versus the DCT.
13. Why does increased consumption of salt lead to increased blood pressure? How does the body respond to increased sodium?
14. How does the renin-angiotensin mechanism restore low blood volume and pressure?
15. Identify the two types of nephrons and indicate the types of urine each produces.
16. Why do you think water reabsorption in the nephron is obligatory first, then facultative second?
17. If blood pH is too acidic, how do the kidneys respond to maintain proper blood pH?
18. How does diet influence urine pH?
19. Say a urinalysis shows that urine pH is 5.5 and specific gravity is 1.030. What do these values say about the food and water intake?
20. Under what conditions is aldosterone released? And ADH?
21. What is a renal clearance test? What items are compared?
22. Explain why hydrostatic pressure in the glomerulus has to be higher than colloid osmotic pressure and capsular hydrostatic pressure in order for filtrate to form. What happens to filtrate formation if hydrostatic pressure in the glomerulus is low?
23. Why are females more prone to urinary tract infections than males?
24. What types of items in the blood are not filtered and removed from blood at the glomerulus? Why?
25. What can we infer about ADH secretion from large outputs of dilute urine? What beverages or substances could cause large outputs of dilute urine? And what is the name for this disorder?

Chapter 24: Urinary System, Continued

Review of the Urinary System

1. Let's say the glomerulus becomes more permeable to red blood cells—allowing them to be lost from the body in urine. What is the name of the disorder that results from an infection in the glomerulus? _____
2. What does the presence of bilirubin or urobilinogen in a urine sample indicate? _____
3. What is the name of the disorder in which protein exists in urine that results from the loss of protein in blood…leading to edema, swelling. _____
4. Name the disorder that is caused by hyposecretion of antidiuretic hormone in which large amounts of urine are put out by the kidney; dehydration results. _____
5. If you have very few solutes in your urine due to drinking lots of water, your _____ will be low, closer to 1.000.
6. What is the term that means "bladder inflammation?" _____
7. Look at the following and indicate which items you'd expect to find in urine and which items you should not…

____glucose	____water
____urea	____potassium
____creatinine	____bilirubin
____urobilinogen	____uric acid
____ketones	____hemoglobin

8. Trace a red blood cell through the kidney; start from the renal artery and travel back to the renal vein.

renal artery → _____ → _____ → arcuate artery → _____ → afferent arteriole → glomerular capillaries → efferent arteriole → peritubular capillaries → (venule) → interlobular vein → _____ → _____ → renal vein

9. The process by which water is reabsorbed in the presence of the hormone ADH is called _____

_____

10. Filtration is a process that occurs in the _____ in the nephron.
11. Obligatory water reabsorption occurs in this portion of the nephron: _____
12. Glucose reabsorption occurs in this portion of the nephron: _____
13. Dieting and starvation can cause this substance to appear in urine (which is abnormal): _____
14. Nephrotic syndrome is also called _____ .
15. Renal calculi means that a person has _____ and this can be caused by a specific gravity closer to _____ .

Answers: 1. glomerulonephritis, 2. liver disorder, 3. proteinuria or albuminuria, 4. diabetes insipidus, 5. specific gravity, 6. cystitis, 7. OK to find in urine are: urea, creatinine, water, potassium, uric acid. Hemoglobin may be found in urine broken down, but not in its whole form, 8. The missing blanks are: segmental artery, interlobar artery, cortical radiate artery, arcuate vein, interlobar vein, 9. facultative (or secondary active) transport…which occurs in the DCT, 10. glomerulus, 11. PCT, 12. PCT, 13. ketones, 14. glomerulonephritis, 15. kidney stones (renal calculi)…1.035

Chapter 24: Urinary System, Continued

Review of the Urinary System

_____1. ADH:
A. promotes urine production
B. inserts aquaporins into membranes in the DCT
C. causes sodium reabsorption
D. promotes loss of potassium in urine
E. regulates calcium ions in urine

_____2. Hydrogen ions are secreted:
A. when blood pH is below 7.35
B. coupled with sodium ions
C. by osmosis
D. in the PCT
E. to maintain proper blood pH

_____3. Most nutrients, like glucose, are reabsorbed in the:
A. DCT
B. PCT
C. collecting duct
D. glomerulus
E. Bowman's capsule

_____4. High pressure in the efferent arteriole causes:
A. increased pressure in the glomerulus
B. decreased pressure in the glomerulus
C. decreased GFR
D. increased pressure in the glomerulus and increased GFR
E. decreased pressure in the glomerulus and increased GFT

_____5. The PCT:
A. filters blood
B. reabsorbs glucose
C. secretes urine
D. is farthest from the Bowman's capsule
E. reabsorbs urea

_____6. The average urinary bladder holds about _____ mL of urine.
A. 100
B. 250
C. 500
D. 1000
E. 10,000

Answers: 1B, 2A and E, 3B, 4D, 5B, 6C

Chapter 25: Fluid, Electrolyte, and Acid-Base Balance

FLUID COMPARTMENTS

About ½ of your body is water, located in 2 main compartments:

1. **Intracellular Fluid (ICF):** about **66%** of the body's fluid is found *within* its trillions of cells (e.g. cytoplasm, nucleoplasm).
2. **Extracellular Fluid (ECF): 33%** of the body's fluids are *outside* the cells; ECF is the "internal environment" that homeostasis keeps constant. There are 2 major subcompartments:
   a) **Interstitial (IF)**: fluid found *outside* cells between the cells of tissues
   b) **Plasma**: fluid within blood vessels
   c) Other ECF:
      1) **Lymph**
      2) **CSF**
      3) **Synovial fluid**
      4) **Fluid of the eye**
      5) **Fluid of the ears**
      6) **Glomerular filtrate**
3. Fluids are separated into these distinct compartments by thin membranes.
   a) Although the **fluid** in each compartment remains relatively stable….
   b) The fluids are in constant **motion** from one compartment to another.
4. **Fluid Balance**: The right amount of water is distributed to each compartment according to its needs.
   a) **Osmosis**: the primary way that water moves between compartments.
   b) The major determinant of fluid balance is the concentration of solutes.

WATER BALANCE

The single largest component of the human body is H_2O (45-75% body weight).

- The percentage of body that is water depends on:
  1. *age* (water content _____ with age)
  2. *gender* (adult males have _____ water than females)
  3. *percent body fat* (% water _____ with increase % body fat). Fat contains no water.
  4. *muscle (% water increases with increase % muscle). Muscle contains more water.*

For Discussion

1. Why do you think dehydration is more problematic for older people and babies?
2. How is dehydration related to a previous term we discussed, *orthostatic hypotension*.
3. Fluid in which compartment is most easily accessed by the body?

Chapter 25: Fluid, Electrolyte, and Acid-Base Balance, Continued

WATER BALANCE

To remain properly hydrated, **<u>water input must equal water output (2.5 L)</u>**

FLUID INTAKE: Intake varies widely, but averages 2500 ml/day – or 2.5 L/day - in healthy adults):

a. **Performed Water:** 90% of water taken in is absorbed from the GI tract (~2250 mL/day):

1) 60% from ingested *liquids* (1500 mL)

2) 30% from ingested *foods* (750 mL)

b. **Metabolic Water:** 10% of our water is produced by cellular metabolism (amounts to about 250mL/day).

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6\mathbf{H_2O} + 6CO_2 + 32\text{-}34\ ATP$$

Regulation of Fluid Intake is controlled by the **Thirst Mechanism**

Dehydration stimulates thirst in 2 ways:

1. Decreased flow of saliva → leads to dry mucosa of mouth and pharynx ("dry mouth").

2. Increased blood osmotic pressure (BOP) stimulates osmoreceptors in "*thirst center*" of the hypothalamus. The osmoreceptors depolarize and ADH is released to retain water (DCT of kidney).

- Both of these events cause a subjective sensation of thirst that motivates us to get a drink.
- *When do you stop drinking?* _____

FLUID OUTPUT: (Output should roughly equal input → 2500 mL/day):

How water is excreted from the body:

1. **Kidneys**: excrete the bulk of fluids from the body, ~1500 mL (1.5 L) (60%) each day in urine.
2. **Skin**: "insensible" evaporation plus "sensible" sweat loses ~ 200 mL/day.
3. **Lungs**: insensible evaporation from moist alveoli during expiration (~700 mL/day).
4. **GI tract**: about 100 mL/day is eliminated in feces.

Regulation of Fluid Output:

1. **Antidiuretic hormone (ADH)**: hormone that increases water reabsorption from the distal convoluted tubules and collecting ducts → _____ urine output.
2. **Aldosterone**: hormone that increases Na^+ reabsorption from the DCT and CD (water follows passively) → _____ urine output.
3. **Hyperventilation**: _____ fluid output through evaporation of water from lungs.
4. **Vomiting/diarrhea**: _____ fluid, protein, and solute loss from GI tract.
5. **Fever/burns**: _____ fluid loss through skin.

For Discussion:

1. List the body compartments for water. What process moves water from one compartment to another?
2. Why does a person start drinking? Why stop?
3. How does ADH correct for blood that is too salty (high osmotic pressure)?

Chapter 25: Fluid, Electrolyte, and Acid-Base Balance, Continued

ELECTROLYTE BALANCE

Electrolyte Balance: water is the "universal solvent" in which a variety of solutes, either electrolyte or nonelectrolytes, are dissolved.

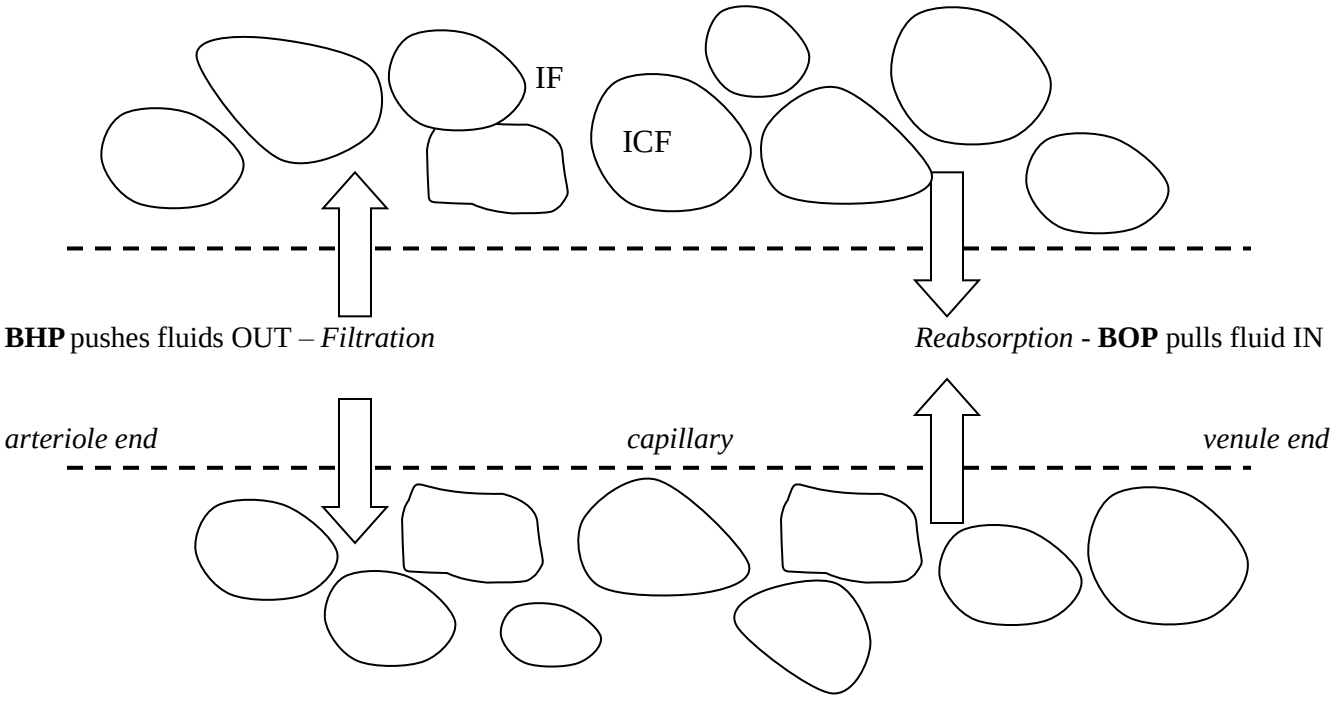
ELECTROLYTE	CONTROLLED BY	FUNCTION	EXCESS CONDITION	DEFICIENCY CONDITION
Sodium (Na^+) *Most common cation in the IF/ECF* Located in the IF/ECF	Aldosterone	• Transmission of nerve impulses • Creates osmotic pressure in the ECF • Sodium concentration in the ECF remains fairly stable	**Hypernatremia** Could be caused by hyperaldosteronism, high salt diet, dehydration Symptoms: SALT (skin is flushed, agitation, low grade fever, thirst)	**Hyponatremia** Could be caused by hypoaldosteronism, water intoxication Symptoms: brain swelling (edema), mental confusion
Calcium (Ca^{2+}) *Most common ion in the body* Located in the IF/ECF	PTH * Calcitonin Calcitriol	• Structural component of bones and teeth • Blood clotting • Muscle contraction • Neurotransmitter release	**Hypercalcemia** Could be caused by hyperparathyroidism Symptoms: groans, moans, bones (lose calcium), stones (kidney stones)	**Hypocalcemia** Symptoms: tetanus of muscles, tingly fingers and toes
Potassium (K^+) Located in the ICF	Aldosterone	• Neuromuscular functioning • Maintains osmotic pressure inside cell	**Hyperkalemia** Symptoms: muscle weakness, cramps, and constipation	**Hypokalemia** Symptoms: muscle weakness, tiredness, cardiac arrhythmias
Chlorine (Cl-) *Most common anion in the ECF* Located in the ECF	Aldosterone	• Forms HCl in the stomach • Maintains osmotic pressure in the ECF	**Hyperchloremia**	**Hypochloremia**
Bicarbonate (HCO_3^-) *Part of the important buffer system in the blood that includes carbonic acid and carbon dioxide*	Aldosterone	**Buffers** are chemical systems that provide quick, short-term compensation (within minutes) for pH changes in the fluids of the body. Buffer systems bind excess H^+ and release H^+ when needed.	**In the case of respiratory acidosis,** bicarbonate ions are filtered by the kidney and can be reabsorbed to increase blood pH. **In the case of respiratory alkalosis**, bicarbonate ions are filtered by the kidney, but *not* reabsorbed. Thus, the blood pH decreases.	**In the case of metabolic acidosis,** bicarbonate ions are the primary way carbon dioxide is transported in the blood. Hypoventilation increases carbon dioxide (and bicarbonate) in the blood. **In the case of metabolic alkalosis**, bicarbonate can be broken down to release carbon dioxide in exhaled breath through hyperventilation.

Chapter 25: Fluid, Electrolyte, and Acid-Base Balance, Continued

REVIEW OF MOVEMENT OF FLUIDS BETWEEN COMPARTMENTS

Movement of Fluids Between Compartments: The continuous movement of body fluids is regulated by osmotic and hydrostatic pressures. Although water moves freely between the compartments, solutes are unequally distributed because of their size and electrical charge. Anything that changes solute concentration in any compartment leads to net water flow.

1. **Between Plasma & Interstitial Compartments**: Movement is across capillary membranes, and depends on 2 *main pressures:*
   a) **Filtration**: (BHP > BOP) the movement of fluid OUT of capillaries at the arterial end of the capillary.
      1) BHP or HP_C (blood hydrostatic pressure): 35 mm Hg at arterial end
      2) BOP or OP_c (blood osmotic pressure): constant, stable 26 mm Hg value along length of capillary
   b) **Reabsorption**: (BOP > BHP) the movement of fluid INTO capillaries at the venule end of the capillary.
      1) BHP of HPc (blood hydrostatic pressure): 15-17 mm Hg at the venule end
      2) BOP or OP_C (blood osmotic pressure): constant, stable 26 mm Hg value along the length of the capillary
2. **Net Filtration Pressure**: the difference between the pressure responsible for moving fluid out of the blood (filtration) and the forces that pull it back into the blood (reabsorption):
   1) At the arterial end of a capillary: NFP = 10 mmHg (net filtration)
   2) At the venous end of a capillary: NFP = -8mmHg (net reabsorption)
3. Most of the fluid (90%) filtered out of the arterial end of a capillary is reabsorbed at the venous end. The small amount that is not reabsorbed passes into the lymph vessels, which return it to the blood via the subclavian veins.



Chapter 25: Fluid, Electrolyte, and Acid-Base Balance, Continued

DISORDERS OF WATER BALANCE

Dehydration occurs when water intake is less than water output. Dehydration can come from water loss (*hypertonic*), sodium loss (*hypotonic*), or loss of both (*isotonic*). In cases of dehydration, cells may shrivel, swell, or remain at equilibrium. Here are three forms of dehydration:

1. **Isotonic dehydration**: If dehydration occurs with equal loss of water *and* electrolytes, we call this form of dehydration *isotonic.* This is the **MOST COMMON** form of dehydration and least fatal because no fluids are moved across membranes.
    - one instance of diarrhea (can become *hypotonic dehydration*)
    - one instance of vomiting (can become *hypotonic dehydration*)
    - temporary fasting
    - one instance of bleeding (hemorrhage – internal or external; can become *hypotonic dehydration*)

2. **Hypotonic (hyponatremic or hypovolemic) dehydration**

[*Remember that hypOtonic environments blOat cells when BOP decreases*]

    - *Loss of salt/solutes or proteins from the blood.*
    - *BOP is lost (or BHP is gained).*
    - *Fluids move from plasma in the capillary → interstitial fluid (EDEMA) → ICF in cell (BLOATS)*

    Causes of hypotonic dehydration
    - hyponatremia (low sodium)
    - hypotonic drip or water intoxication
    - nephrosis (loss of proteins in urine)
    - infection and inflammation (proteins leak to interstitial space)
    - severe burns (loss of proteins)
    - severe diarrhea/vomiting (loss of sodium from blood)
    - lymphatic obstruction (proteins lost to interstitial space)
    - liver disorders (loss of proteins from blood)
    - diuretics (inhibiting sodium reabsorption)
    - hemorrhage (bleeding)

Chapter 25: Fluid, Electrolyte, and Acid-Base Balance, Continued

DISORDERS OF WATER BALANCE

3. **Hypertonic (hypernatremic) dehydration**
    - *Occurs due to loss of water (or gain of salt/protein) from the blood.*
    - *BHP is lost (or BOP is gained).*
    - *Fluids move from ICF in cell (SHRIVEL) → interstitial fluid → plasma in capillary.*

    Causes of hypertonic dehydration
    - hypernatremia (excess sodium)
    - drinking seawater (increase sodium in blood relative to water in blood)
    - high salt diet (increases BOP relative to BHP)
    - hyperaldosteronism (promotes sodium reabsorption)
    - diabetes insipidus (loss of excess fluid in the urine)
    - diabetes mellitus (loss of excess fluid in the urine)
    - fever (promotes sweating and a loss of more water than salt from the blood)
    - sweating (loss of more water than salt from blood)

Hydration or **overhydration** can cause an accumulation of fluid in intercellular space where interstitial fluids are located (called **edema**). Overhydration can be due to an increased permeability of the capillaries since fluid leaks out and cannot return. (*Anti-inflammatory drugs block fluid from leaving the capillaries, forcing fluid to stay in the capillary. Since fluid is not allowed to leave the capillary, it can not travel into the interstitial space.*)

1. **Hypotonic Hydration (water intoxication)**: ECF has excess water. Sodium may be normal, but excess water will dilute the interstitial fluid (making it hypotonic) and water enters cells; cells swell. As a result, blood pressure appears normal. Aldosterone and ADH are inhibited and urine output increases.
    - **Increased capillary hydrostatic pressure** and **permeability** causes increased filtration at capillary beds (such as from blocked venous valves, localized blood vessel blockage, congestive heart failure, high blood volume, ongoing inflammatory response which causes capillaries to become porous)
    - **Hyponatremia** can occur along with hypotonic hydration which promotes cell swelling (edema). **Symptoms of water intoxication**: vomiting, muscle cramps, cerebral edema, convulsions, coma.
    - **Hindered fluid return** often indicates an imbalance of the colloid osmotic pressure on both sides of the capillary membrane (such as from hypoproteinemia-low levels of plasma protein in the blood-this problem forces fluids out at the arterial end but fluids fail to return to the capillary at the venous end; blocked or removed lymphatic vessels). Proteins leaked into the interstitial space promote edema.

Chapter 25: Fluid, Electrolyte, and Acid-Base Balance, Continued

FLUID BALANCE PROBLEMS

Solving F/E Problems

(use the information on the previous 2 pages to help you)

- *Which pressure is lost - BHP or BOP?*
- *Determine if the condition is isotonic dehydration, hypotonic dehydration, hypertonic dehydration, or hypotonic hydration (overhydration).*
- *Describe the movement of fluid (plasma→IF→ICF or ICF→IF→plasma). Determine if cells will shrink or swell. Indicate when edema may occur.*

1. **Example:** Why does infection in the right hand result in edema? Infection leads to loss of blood proteins.
   - BOP is affected; infection decreases BOP
   - Hypotonic dehydration
   - If blood osmotic pressure is decreased, then interstitial fluid is increased (edema is swelling or accumulation of fluid in the interstitial space). Cells swell as fluid moves from the plasma to IF to ICF.

2. How would a person drinking large amounts of sea water affect the normal movement of fluid between the plasma and the interstitial fluid? Sea water causes hypernatremia and loss of fluid from the blood.

3. How would extensive diarrhea (loss of solutes and proteins) affect normal movement of fluid between the plasma & interstitial fluid?

4. Extensive internal hemorrhage (loss of blood proteins)

5. Lymphatic obstruction in the axillary area of the left arm (loss of blood proteins)

6. Diabetes mellitus (loss of fluids)

7. Hyponatremia (loss of blood sodium)

8. High blood pressure, such as 175/110 mm Hg (imbalance of low sodium compared to fluids)

9. Hypertonic intravenous drip (loss of fluids in relation to blood sodium levels)

10. Glomerulonephritis (loss of blood proteins in urine)

Chapter 25: Fluid, Electrolyte, and Acid-Base Balance, Continued

MORE FLUID-ELECTROLYTE PROBLEMS

- *Determine which pressure is affected (BHP or BOP). Determine how the pressure is altered. Is it increased or decreased from normal?*
- *Determine each condition as isotonic dehydration, hypotonic dehydration, hypertonic dehydration, or hypotonic hydration (overhydration).*
- *As a result of the pressure change, describe the movement of fluid (plasma→IF→ICF or ICF→IF→plasma). Determine if cells will shrink or swell. Indicate when edema may occur.*

11. Kwashiokor (starvation and loss of blood proteins)

12. Hepatitis (inflammation of the liver; loss of blood proteins)

13. Tumor of the adrenal gland causing hyperaldosteronism (excess sodium and loss of fluids)

14. Diabetes insipidus due to insufficient ADH (loss of fluids)

15. Infection in the hand from a dog bite (loss of blood proteins)

16. Drinking alcohol (loss of fluids)

17. Kidney infection (loss of blood proteins)

18. Low blood pressure, such as 80/45 mm Hg (loss of fluids)

Answers

11. ↓ BOP, cells swell due to decreased reabsorption at the venule end of capillary as fluids move plasma →IF→ICF; hypotonic dehydration
12. ↓ BOP, cells swell due to increased hypotonic fluid in the interstitial space as fluids move plasma → IF → ICF; hypotonic dehydration
13. ↓ BHP (or a ↑ BOP) due to excess sodium; cells shrivel due to increased reabsorption as fluids move ICF → IF → plasma; hypertonic dehydration
14. ↓ BHP; cells shrivel since fluids are lost in the urine without ADH present in the DCT of nephron. Fluids move from ICF→IF→plasma. Hypertonic dehydration.
15. ↓ BOP; cells swell due to presence of inflammation where infection occurs. Fluids move from plasma→IF→ICF; hypotonic dehydration.
16. ↓ BHP; cells shrivel due to lessened filtration at arteriole end of capillary; fluid stays in capillary and is removed from the body during renal filtration. Fluids move from ICF→IF→plasma. Hypertonic dehydration.
17. ↓ BOP; cells swell when excess fluid travels from plasma → IF→ICF rather than getting reabsorbed back into the blood stream. With kidney infection, proteins can be lost when the glomerular capillaries become leaky. Proteins escape in urine; hypotonic dehydration. Hypotonic dehydration.
18. ↓ BHP; fluids are not pushed out at arteriole end of capillary; more fluids are reabsorbed into the capillary at the venule end. Fluid moves from ICF→IF→plasma, gets filtered by the glomerulus, and removed by the body in urine. Hypertonic dehydration.

Chapter 26: Reproductive System

OVERVIEW

1. **Gonads** are the primary sex organs: male testes & female ovaries. They are (mixed) heterocrine glands because they: (1) make and discharge gametes into ducts (exocrine), and (2) they secrete sex hormones into the blood (endocrine).
2. **Gametes**: special reproductive cells: male sperm & female eggs. They are produced by meiosis in the gonads, and have a haploid number of chromosomes (all other body cells are diploid).
3. **Fertilization**: union of a sperm with an egg. It results in the formation of a zygote.
4. **Zygote**: the first cell of a new individual. This diploid cell divides repeatedly by mitosis to become an **embryo**, and later a **fetus** (after 8 weeks of pregnancy).

TESTES

- **Testes Size and Shape**: these primary organs (glands) are olive sized, 1 ½" long and 1 inch wide
- **Testes Structure**: surrounded by connective tissue called *tunica albuginea*, which also divides the testes into about 200-300 different compartments called lobules:
  - **Each lobule** contains 1-4 coiled **seminiferous tubules**, the place where sperm are formed. These tubules empty sperm into another set of tubules, *rete testis*. Sperm travel through the rete testis to the *epididymis.*
  - **Interstitial cells** are clusters of cells in between the seminiferous tubules; they secrete testosterone
- **Testes Function**: Produce 1) sperm and 2) testosterone

MALE DUCT SYSTEM

- **Epididymis**
  - **Location/Structure**: coiled tube (20 feet long is unwound) that caps the superior part of the testis.
  - **Function**: provides a temporary storage site for the immature sperm that enter it from the testis. It takes 20 days for sperm to swim along the epididymis to mature and grow tails. During ejaculation, the smooth muscles in the walls contract to expel sperm into the next part of the duct system, the **ductus deferens**
- **Ductus (Vas) Deferens**
  - **Location**: thick-walled 18" long duct that runs from the epididymis through the inguinal canal into the pelvic cavity and arches over the bladder. Once at the bladder, it terminates in an ampulla.
  - **Structure**: enclosed with blood vessels, nerves, in a connective tissue sheath, **spermatic cord.** The end of vas deferens empties into the **ejaculatory duct.**
  - **Function**: propel live sperm from their storage sites into the urethra. At ejaculation, the walls create peristaltic waves to squeeze sperm forward
  - ***Vasectomy*:** vas deferens is cut and tied under local anesthesia. Sperm are still produced, but they degenerate. Blood vessels are not cut and hormones are still made, so testosterone levels are not affected.
- **Ejaculatory Duct**
  - **Location**: 1" tubes located behind the bladder
  - **Structure**: formed from the union of the vas deferens with a duct coming from each seminal vesicle
  - **Function**: transport sperm into the prostate – they then continue on to the urethra

Chapter 26: Reproductive System, Continued

MALE DUCT SYSTEM, continued

- **Urethra**
  - **Location**: extends from base of bladder to tip of penis
    - **Prostatic urethra**: surrounded by **prostate** (gland)
    - **Membranous urethra**: distance from prostatic urethra to penis
    - **Spongy (penile) urethra**: running the entire length of penis
  - **Structure**: 8" long tube that connects to the ejaculatory duct and travels through the prostate, urogenital diaphragm, and out the length of the penis
  - **Function**: carries both urine and sperm to the body exterior. Urine and sperm never pass at the same time due to a sphincter at the base of the bladder. When ejaculation occurs and sperm enter the prostatic urethra from the ejaculatory ducts, the bladder sphincter constricts and prevents passage of urine into urethra and prevents passage of sperm into urinary bladder.

ACCESSORY GLANDS

Semen: milky white mixture of sperm plus the secretions of the 3 accessory glands. An average male ejaculates between 2.75 – 3.5 mL, containing 50-150 million sperm/mL (so one ejaculation could contain 450 million sperm!). Semen acts as a transportation medium, neutralizes the acidity of the male urethra & female vagina, and provides nutrients for the sperm. (pH of semen = 7.2 – 7.6)

- **Seminal vesicles**: two glands located at the base of bladder and produce 60% of semen. Thick, yellowish, sugary secretion nourishes and activates sperm as well as neutralizes the acidity of the female's vagina. Sperm and seminal fluid mix in the ejaculatory duct and enter the prostatic urethra.
- **Prostate gland**: a single, donut-shaped gland circling the urethra just below the bladder. Its secretes a milky, slightly acidic fluid containing prostaglandins that activates sperm and improves sperm motility.
  - **Prostate enlargement** (benign prostatic hyperplasia or BPH) causes painful and difficult urination and increases the risk of bladder infections and kidney damage. Common in elderly men. **Prostate cancer** is the 3rd most common cancer in men.
- **Bulbourethral (Cowper) glands**: 2 pea-sized glands inferior to the prostate gland. Produce a thick, clear mucous that drains into the penile urethra. It is first to pass down the urethra during sexual arousal. Believed to cleanse the urethra, neutralizes traces of acidic urine and serves as a lubricant.

EXTERNAL MALE GENITALIA

- **Scrotum**: pouch of skin that hangs outside the abdominal cavity and house the testes. The testes must be at a temperature cooler (by about 3 ° C) than the body for sperm production. The *cremaster muscle* pulls the testes closer to the body when it's cold.
- **Penis**: designed to deliver sperm into female reproductive tract. Internally, it contains the urethra and 3 cylindrical masses of erectile tissue that fill with blood during an erection.

  Three regions: 1) shaft, 2) glans penis (enlarged tip), 3) prepuce/foreskin (cuff of skin at proximal end of glans)

Chapter 26: Reproductive System, Continued

Review of the Male Reproductive System Anatomy

Choose from the letters below; letters may be used more than once.

A. Testes
B. Epididymis
C. Vas deferens
D. Penis
E. Scrotum
F. Seminal vesicles
G. Prostate gland
H. Cowper's/bulbourethral gland

_____1. The organs in which sperm are formed are called ___.

_____2. The tube that carries sperm from the epididymis, through the inguinal canal, and to the prostate gland.

_____3. This coiled tube that sits atop the testes is where sperm are matured and gain the ability to swim (with a tail).

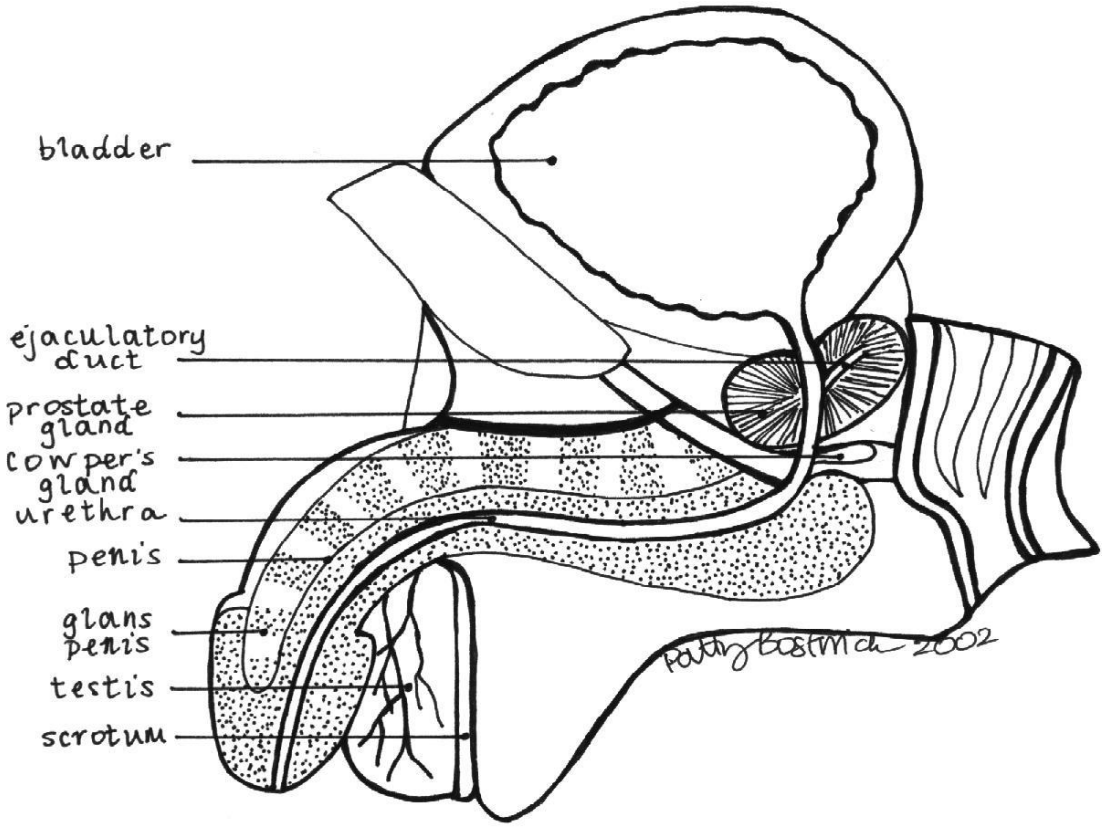
_____4. The gland that secretes the thick, yellowish, nutrient-rich fluids to activate sperm.

_____5. This sac of skin houses the testes.

_____6. The organ through which both urine and semen leave the male body.

_____7. This gland produces thick, clear mucus that cleanses the urethra of acidic urine prior to ejaculation.

Answers: 1A, 2C, 3B, 4F, 5E, 6D, 7H



Chapter 26: Reproductive System, Continued

SPERMATOGENESIS AND SPERMIOGENESIS
PROCESS OFMAKING SPERM CELLS

- **Sperm production**: begins at puberty and continues throughout life.
- **Time of process**: 64 to 72 days (about 10 weeks). Each spermatogonium produces 4 mature haploid sperm; the whole process taking about 72 days. Once ejaculated, they live for about 48 hours in the female.

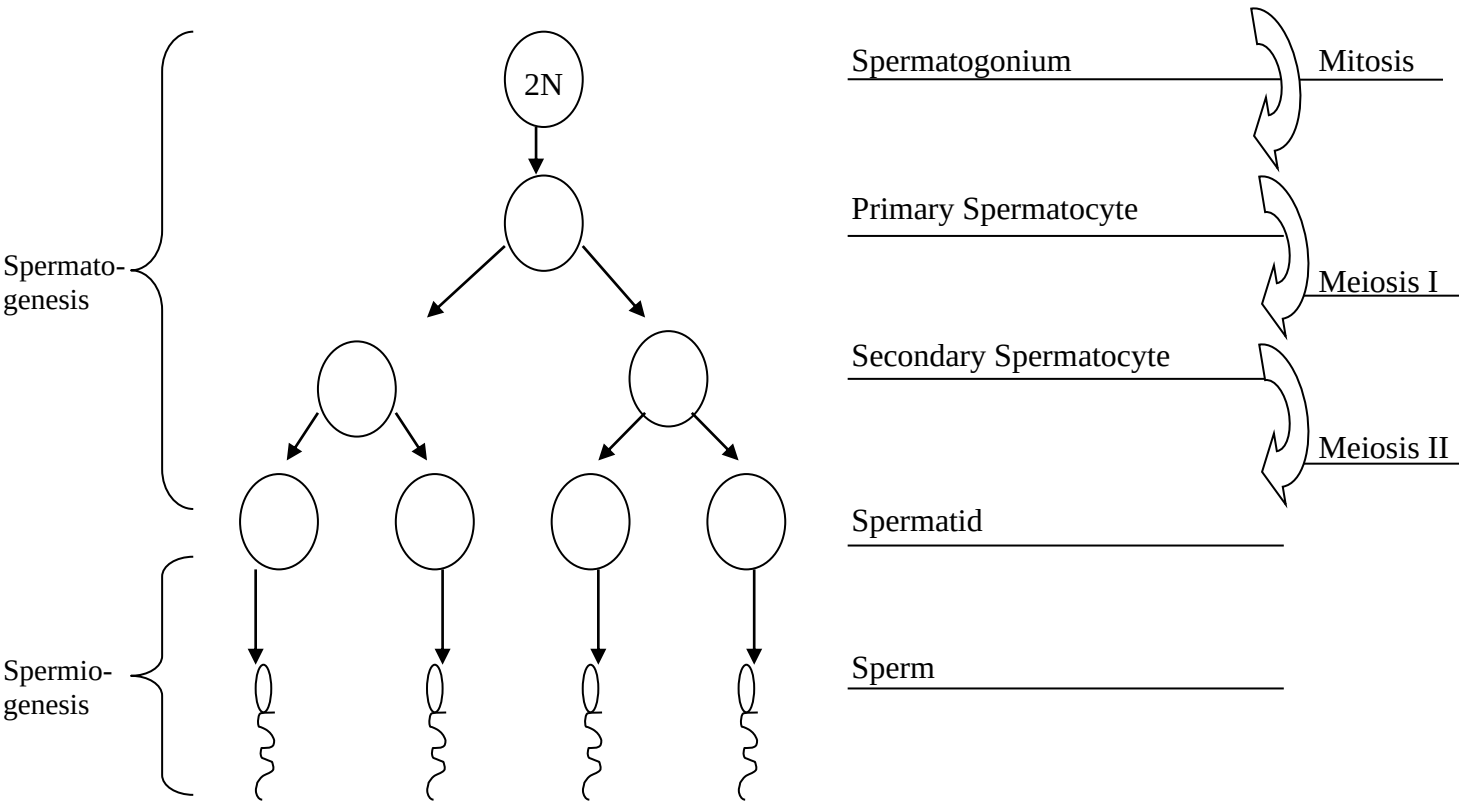
Spermatogenesis:

1. **Spermatogonia**: Diploid (2N) cells (containing 46 chromosomes) lining the walls of the seminiferous tubules; they divide by mitosis, and one daughter cell moves away from the wall, & becomes a …
2. **Primary Spermatocyte**: Diploid cell that undergoes meiosis I to form 2…
3. **Secondary Spermatocytes**: Two haploid (1N) cells (containing 23 chromosomes), each with *double-stranded* chromosomes. They undergo meiosis II, resulting in the formation of 4…
4. **Spermatids**: small, round cells are produced with haploid *single-stranded* chromosomes and large nuclei. These non-motile cells must undergo a streamlining process, known as **spermiogenesis**, to become….

Spermiogenesis

5. **Sperm**: Spermatids lose most of their cytoplasm, and their nucleus condenses into a head, with an **acrosome** (specialized lysosome containing enzymes that will enable the sperm to penetrate & enter egg). They also develop a **tail** (flagellum) for locomotion, and have a mid-piece that contains numerous mitochondria to provide the energy for locomotion.

SPERMATOGENESIS AND SPERMIOGENESIS



Chapter 26: Reproductive System, Continued

MALE REPRODUCTIVE SYSTEM

HORMONES AND MALE REPRODUCTION

1. After birth, testes of a boy remain dormant until puberty (age 11-15). Then, the anterior pituitary begins to secrete 2 gonadotropic hormones in response to GnRH from the hypothalamus:

   a. **FSH**: acts on seminiferous tubules in testes to stimulate spermatogenesis

   b. **LH**: stimulates the interstitial cells to secrete the hormone testosterone

   Since both of these hormones travel in the bloodstream, a vasectomy does not affect their production. Vasectomies only severe the vas deferens, making it impossible for sperm leave the body and leaving testosterone production intact.

   c. **Inhibin** is a hormone that is produced in response to high levels of FSH. Inhibin decreases sperm production—when sperm count is high, inhibin release increases to lower the sperm count. Likewise, when sperm count is low, inhibin production decreases. Both males and females produce inhibin to down regulate (or decrease) FSH.

2. **Testosterone**: male steroid hormone (made from cholesterol). It controls 3 things:

   a. **Growth & Development of Sex Organs**: in the embryo, it's responsible for the formation of the male genitalia, and it causes the testes to *descend* into the scrotum. After birth, it stops until puberty, when it causes the penis and scrotum to grow in size.

   b. **Final Maturation of Sperm**: it must be present, along with LH, for spermatogenesis to go to *completion.*

   c. **Male Secondary Sex Characteristics:**

      1. male hair pattern on body axillary and pubis regions
      2. deep voice
      3. skin thickens and becomes oilier
      4. bones grow
      5. skeletal muscle increases

Chapter 26: Reproductive System, Continued

Review of Male Reproductive System

1. List the 3 accessory glands of the male reproductive system and describe their contributions to semen.
2. List the pathway of sperm from its production site in the testes to the outside of the body.
3. Explain meiosis I and II as it relates to spermatogenesis.
4. Explain why a vasectomy does not affect sperm and testosterone production.
5. List and discuss the three items testosterone affects.
6. Explain the changes in sperm structure as it occurs in spermiogenesis.
7. Explain the role of the epididymis in the male reproductive system.
8. Discuss the role of the cremaster muscle in sperm production.
9. Describe the two functions of the male urethra.
10. Explain how prostate enlargement can affect the functioning of the male urinary and reproductive systems.
11. Discuss how FSH and LH affect activities in the testes.
12. Identify the differences between a spermatid and a sperm; identify the differences between a primary spermatocyte and a secondary spermatocyte.
13. Trace the sperm from its site of maturation in the epididymis until it reaches the ejaculatory duct.
14. How many weeks will pass until a spermatogonium is transformed into a sperm?
15. What cord is found passing through the inguinal canal in a male's body?
16. What will you find housed in the spermatic cord in a male's body?
17. How many spermatocytes are formed after meiosis I?
18. What is the chromosome number of a spermatocyte?
19. What is the chromosome number of a sperm?
20. What's the difference between a secondary spermatocyte and a spermatid?
21. What's the difference between a spermatid and a sperm?
22. How many sperm are formed from one spermatogonium?
23. How many weeks does it take to form a mature sperm from a spermatogonium?
24. Describe what happens in spermiogenesis.
25. What is the end result of spermatogenesis in terms of number of cells and their ploidy number (diploid/haploid)?

Chapter 26: Reproductive System, Continued

FEMALE REPRODUCTIVE SYSTEM

INTERNAL STRUCTURES

- **Ovaries:** The female gonads; paired, almond-shaped heterocrine glands held in the upper peritoneal cavity by ligaments. Formation of secondary oocyte occurs here, as does the production of the female sex hormones (estrogen & progesterone).
- **Uterine (Fallopian) Tubes**
  - **Structure:** 4 inches long connect the ovary to the uterus
  - **Function:** 1) Receives and carries ovulated oocyte, 2) provides a site for fertilization, 3) the oocyte is carried to uterus by peristalsis and a rhythmic beating of cilia
  - **Regions**
    - **Infundibulum**: funnel-shaped, distal end of each tubes; draped around an ovary & encircled with a fringe of finger-like projection called **fimbriae.**
    - **Ampulla**: widest, longest portion of the tube, where fertilization usually occurs.
    - **Isthmus**: short, constricted part where the tube joins the uterus.
- **Uterus**
  - **Location**: The uterus lays on top of the bladder in a horizontal position between bladder and rectum.
  - **Function**: receive, retain, and nourish a fertilized egg→embryo→fetus for 40 weeks. In women who have never been pregnant, it's the size of a pear
  - **Structure**

    Three layers:
    - **Endometrium**: the highly vascular inner lining of mucosa where a fertilized egg burrows for **implantation**. **Two layers**: **stratum functionalis** (which is shed each month during menstruation), and **stratum basalis** (deep layer which produces a new functionalis each month)
    - **Myometrium**: bulky middle layer of uterus composed of **smooth** muscle; contracts during labor to push out baby, during an orgasm, or during menstrual cramps.
    - **Epi (peri) metrium**: outermost layer, or the visceral peritoneum.

    Regions:
    - **Fundus**: dome-shaped area above where the fallopian tubes enter
    - **Body**: major, tapering, central portion (uterine cavity inside).
    - **Cervix**: narrow outlet which protrudes into vagina below. Inside is the cervical canal, which communicates with the vagina via the external os. The cervical mucosa secretes thick mucus that blocks the entry of sperm (except at ovulation, when it thins out and allows sperm to pass). A yearly PAP smear is the best way for early detection of cervical cancer.

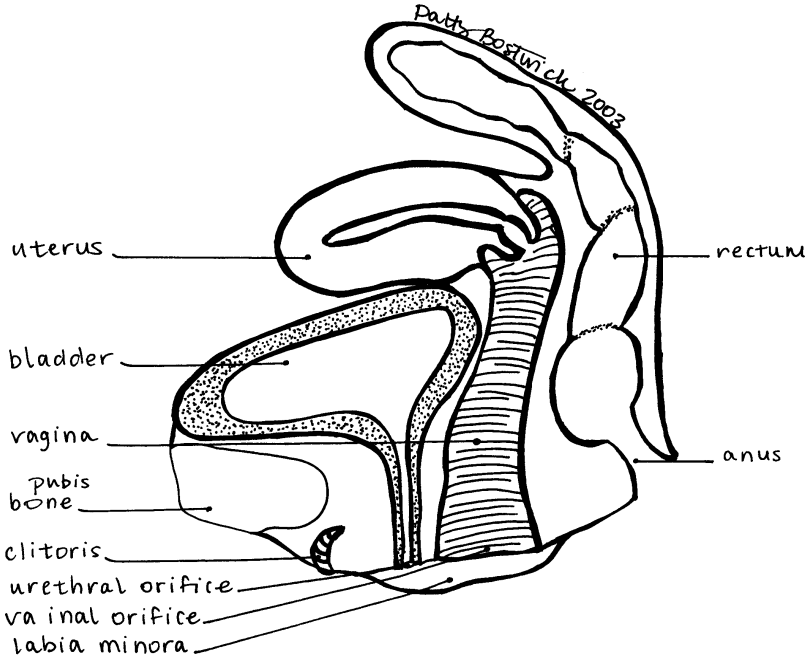
Chapter 26: Reproductive System, Continued

INTERNAL STRUCTURES, continued

- **Vagina**
  - **Location**: between bladder and rectum and extends from cervix to exterior
  - **Structure**: 3-4 inches long receptacle for penis during sex; also serves as the birth canal.
    - **Vaginal fornix**: the recess surrounding the cervix where the vaginal attaches. This indention makes use of contraceptive diaphragm possible.
    - **Muscularis**: the layer of **smooth** muscle in the vaginal wall that enables it to *stretch* during intercourse or delivery.
    - **Vaginal orifice**: the opening to the vagina (posterior to the urethral orifice). In virgins, it is partially closed by a thin fold of very vascular membrane called the **hymen** (it can bleed when ruptured).

EXTERNAL GENITALIA = VULVA

- **Labia majora**: 2 elongated folds of skin, covered by pubic hair, and containing lots of adipose tissue, oil and sweat glands. These are the female counterparts of the male **scrotum.** They enclose the …
- **Labia minora**: 2 thin, hairless folds of skin, medial to the labia majora.
- **Clitoris**: small, cylindrical mass of erectile tissue anterior to the urethral orifice. Plays a role in female sexual arousal. Homologous to the male **glans penis.**
- **Mons pubis:** fatty, rounded area overlying the pubic symphysis and is covered with pubic hair after puberty.
- **Vestibule**: an area enclosed by labia majora; contains opening to vagina and urethra
- **Greater vestibular glands**: produce mucous and flank the vagina



Chapter 26: Reproductive System, Continued

Review of the Female Reproductive System Anatomy

Choose from the letters below; letters may be used more than once.

A. Ovaries
B. Uterus
C. Fallopian Tube
D. Vagina
E. Endometrium
F. Myometrium
G. Perimetrium
H. Cervix

_____1. The female reproductive gland that produces oocytes, or eggs.

_____2. This organ is the preferred site of implantation of a fertilized egg due to its muscular myometrium and thick, vascularized endometrium.

_____3. This birthing canal is about 3-4 inches in length and is connected to the uterus.

_____4. These tubes connect the ovaries to the uterus. Each month these tubes carry an oocyte (egg) toward the uterus.

_____5. The muscular layer of the uterus is called the ___.

_____6. The parts of the female anatomy that close off the opening to the uterus is the ___.

_____7. The innermost lining of the uterus that is sloughed off during menstruation is the ____.

_____8. The lining of the uterus where a fertilized egg implants at the start of pregnancy is the ____.

Answers: 1A, 2B, 3D, 4C, 5F, 6H, 7E, 8E

Chapter 26: Reproductive System, Continued

OOGENESIS

Oogenesis. The formation of haploid egg (ova/gametes) by mitosis within the female ovary & fallopian tube. The process takes years to complete.

a. **Oogonium** (oogonia = pl.): *diploid* cells, formed in the ovary of a 3-month old female embryo. They divide by mitosis, enlarge and become…

b. **Primary oocytes**: female baby born with about ~400,000 of these diploid cells that *begin Meiosis I*, but "stall" in Prophase I (until puberty). They are surrounded by a layer of flattened cells; this sac-like structure is called a primordial follicle.

c. At puberty, under the influence of FSH, 1 of these follicles completes Meiosis I *each month*, producing 2 haploid cells of *unequal size:*

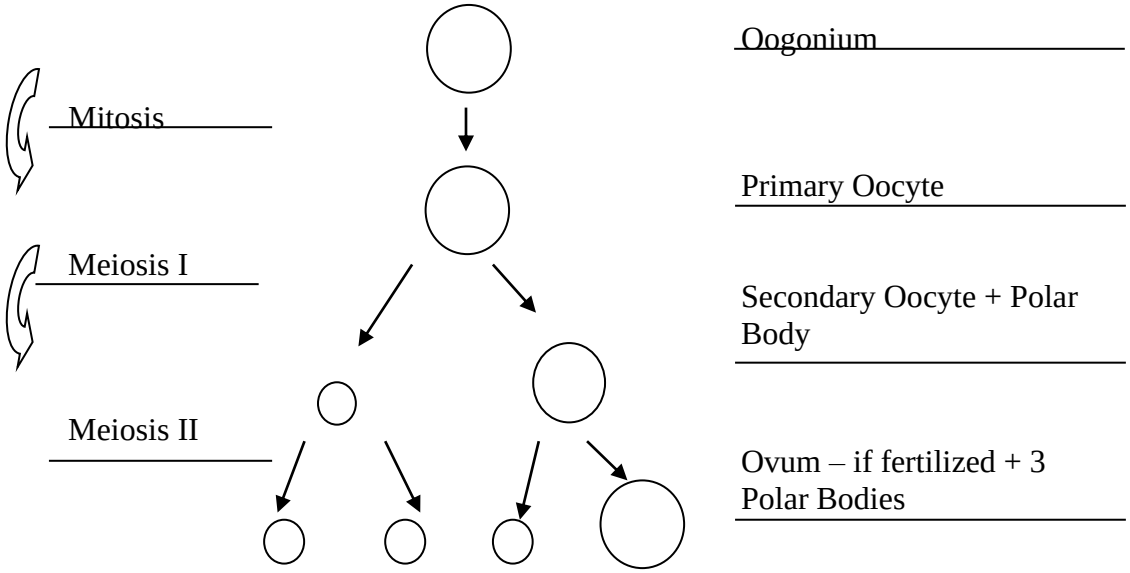
1. **First polar body**: very small packet of discarded chromosomes, it usually undergoes Meiosis II, and then both polar bodies disintegrate.
2. **Secondary Oocyte**: larger, *haploid double stranded* cell that received most of the cytoplasm; it is surrounded by a fluid-filled chamber called the mature, or Graafian follicle. This cell *begins* Meiosis II, but stops in metaphase II. It is this secondary oocyte that is ovulated each month and lives for 24 hours. If it is *not fertilized*, it deteriorates. But…

d. If that secondary oocyte is fertilized (in the fallopian tube), Meiosis II goes to completion, again producing 2 *haploid single stranded* cells of unequal size:

1. **Polar body**: tiny haploid cell that disintegrates.
2. **Ovum**: large cell; mature female gamete (haploid single-stranded chromosomes)

- Unlike spermatogenesis, the end products of oogenesis = 3 tiny polar bodies and only 1 large ovum.
- The unequal divisions of cytoplasm ensure that a fertilized egg will have enough nutrients for the 7-day journey to the uterus.
- Since women ovulate for about 40 years (once a month), a fraction of her 400,000 potential eggs are released.

OOGENESIS



Chapter 26: Reproductive System, Continued

OVULATION

Ovulation: Once a month, a Graafian follicle moves to the surface of an ovary and ruptures, releasing a secondary oocyte.

1. The oocyte is swept into the fallopian tube (which does not touch the ovary) by the cilia in the infundibulum, and is moved along the tube by peristalsis (of smooth muscle) as well as the beating of cilia lining the tube.
2. Fertilization (*if it occurs*) usually takes place in the fallopian tube, and may occur up to 24 hours following ovulation. *Why 24 hours?* _____
3. After a sperm penetrates the secondary oocyte, it completes meiosis II, forming a mature ovum. Once the male and female nuclei unite, this fertilized ovum is called a zygote.
4. The **zygote** undergoes repeated mitotic divisions (cleavage) and arrives at the uterus in about 7 days where it embeds in the uterus – in the endometrium lining as a **blastocyst**.
5. Unfertilized oocytes disintegrate and pass out in menstrual flow.

FEMALE HORMONES

The female ovaries are dormant until puberty (age 11-13), at which time, the pituitary gland, stimulated by GnRH from the hypothalamus, begins to secrete two gonadotropic hormones (which act on the ovaries):

a. **FSH**: causes an ovarian follicle to grow, mature and begin secreting estrogen.

b. **LH**: causes a mature follicle to rupture, in ovulation; and the empty follicle become a corpus luteum ("yellow body") which begins to secrete the hormone progesterone, as well as estrogen.

Two Ovarian (Steroid) Hormones:

a. **Estrogens**: this group of female hormones has several effects:
   1. Promotes growth and development of female reproductive structures.
   2. Promotes oogenesis and follicle growth in the ovary.
   3. Causes endometrium to grow and thicken each month. (Proliferative phase)
   4. Causes "growth spurt" at puberty, but also causes closure of the epiphyseal plates, so girls grow at an early age (ages 12-13) but stop growing sooner (ages 15-17).
   5. **Female secondary sex characteristics**
      a. growth of breast tissue
      b. increased fat deposits in hips and breasts
      c. growth of pubic hair & axillary hair

b. **Progesterone**
   1. Works with estrogen to prepare the endometrium for the implantation of a fertilized ovum
   2. Causes endometrial glands to become secretory
   3. Prepares the mammary glands for milk secretion. (pro = for; *gestation* = pregnancy).

Chapter 26: Reproductive System, Continued

ESTABLISHING THE MENSTRUAL CYCLE

Menarche: the very *first* menstruation; it usually occurs in girls around twelve years of age, as the hypothalamus begins to secrete GnRH.

1. **Climacteric**: With age, estrogen production declines, & menstrual periods become erratic & increasingly shorter in length. Eventually, ovulation & menses cease entirely.
2. **Menopause**: When a whole year has passed without menstruation, this has occurred (normally between the ages of 46-54). "Symptoms" include: no menstruation for one year, estrogen levels drop, irritability and depression, hot flashes, thinning of skin, loss of bone mass.

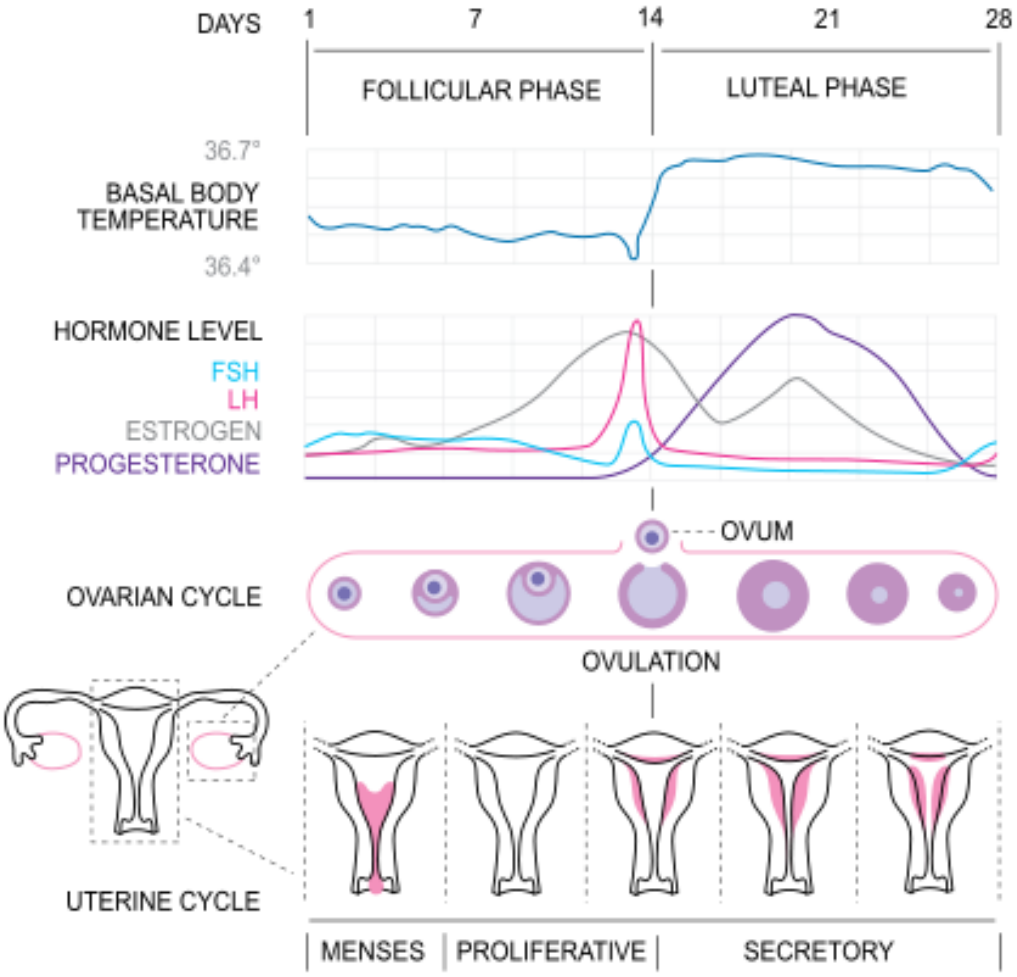
MENSTRUAL CYCLE

The Menstrual Cycle: The series of cyclic changes that the uterine endometrium goes through each month as it responds to changing levels of estrogen & progesterone in the blood. The "typical cycle" lasts 28 days, with ovulation occurring mid-cycle.

1. **The Menstrual Phase** (Days 1-5):
   a. **Menstruation**: periodic discharge of blood and dead endometrial cells (*stratum functionalis*) through the vagina. The uterine lining is shed due to ↓ levels of estrogen & progesterone.
   b. GnRH from the hypothalamus stimulates the anterior pituitary to produce and release FSH. FSH stimulates the growth of several ovarian follicles, which in turn begin to secrete estrogen by day 5.
2. **Proliferative Phase** (Days 6-14):
   a. Growing follicles produce estrogen which stimulates rebuilding of the endometrium (cells of the *stratum basalis* undergo mitosis to produce a new *functionalis*). During this phase, the endometrium doubles in thickness, and increases in vascularization.
   b. A secondary matures and forms a **Graafian follicle** that produces a bulge on the ovary's surface.
   c. High levels of estrogen in the blood *exert positive feedback* on the anterior pituitary, causing a sudden, burst-like release of LH around day 14.
   d. **Ovulation**: This "LH-Surge" causes the graafian follicle to swell & burst, releasing a secondary oocyte into the Fallopian Tube (~day 14). *There are several signs that often accompany ovulation:* increase in basal body temperature of ½ °F; cervical mucus (normally thick) becomes thinner; "Mittelschmerz" – twinge of abdominal pain (as ovary stretches)
3. **Secretory Phase** (Days 15-28):
   a. The ruptured Graafian follicle collapses, and transforms into a "yellow body", called the **corpus luteum**, which, under the influence of LH, begins to secrete progesterone and estrogen. (*Notice the surge of progesterone*)
   b. Rising levels of progesterone prepare the endometrium for a fertilized ovum (increases vascularization, and activity of uterine glands).
   c. Progesterone also causes the cervical mucus to become viscous again, forming a *cervical plug*, which blocks sperm entry.

Chapter 26: Reproductive System, Continued

OVARIAN AND MENSTRUAL CYCLE



IF THE OOCYTE IS NOT FERTILIZED:

a. Declining levels of LH cause the **corpus luteum** to degenerate, resulting in ↓ production of progesterone and estrogen.

b. Since the endometrium *depends* on estrogen & progesterone for its maintenance, their decline causes the stratum functionalis to deteriorate and slough off. Blood also oozes from weakened capillaries in the walls, menstruation begins.

c. Back to DAY 1 → since the anterior pituitary is no longer *inhibited* by estrogen and progesterone, it begins secreting FSH, and new follicles begin developing (the menstrual cycle starts over again).

IF THE OOCYTE IS FERTILIZED

a. If sperm enter the vagina near the time of ovulation, within an hour, they swim up the vagina, uterus, and into the fallopian Tubes. They release enzymes that begin to digest the outer coverings around the secondary oocyte, until one sperm penetrates the oocyte's membrane (no others can then enter → monospermy).

b. After the gametes unite (fertilization), the secondary oocyte finishes Meiosis II, becoming an ovum (and ejecting a second polar body). The *true* moment of fertilization occurs as the male & female nuclei fuse, forming a diploid cell called the zygote – our cover image.

Chapter 26: Reproductive System, Continued

Review of Reproduction

_____1. Sperm are matured during spermiogenesis in the:
A. vas deferens
B. epididymis
C. testes
D. rete testis
E. ejaculatory duct

_____2. Oogenesis stalls in meiosis II when a _____ has been produced.
A. oogonium
B. primary oocyte
C. secondary oocyte
D. ovum
E. spermatid

_____3. Fertilization occurs when a _____ and sperm unite.
A. spermatogonium
B. oogonium
C. primary oocyte
D. Graafian follicle
E. secondary oocyte

_____4. Which hormone causes ovulation in females and testosterone production in males?
A. FSH
B. estrogen
C. testosterone
D. progesterone
E. LH

_____5. How many hours does a secondary oocyte live?
A. 6
B. 12
C. 24
D. 36
E. 72

_____6. Which male accessory gland produces a clear mucus to cleanse the urethra of acidic urine?
A. Cowper's (bulbourethral) gland
B. prostate
C. seminal vesicles
D. testes
E. epididymis

Answers: 1B, 2C, 3E, 4E, 5C, 6A

Focus Topics on the Reproductive System for the Final Exam

- What is oogenesis?
- What type of cell is ovulated?
- List the hormones that control ovulation.
- Where does fertilization typically occur?
- Where does implantation typically occur?
- What is spermatogenesis? What does spermiogenesis accomplish?
- How many sperm are produced from one spermatogonium via spermatogenesis?
- What hormones control spermatogenesis?
- Trace the route of sperm from production to the urethra.
- List the male accessory glands and the secretions each makes.

LAST PAGE OF THE COURSEPACK