BIOLOGY 138

Semester 2 Study Guide – Version 1.10

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I. Mitosis and Meiosis

Mitosis

Interphase includes three stages, referred to as G_1, S and G_2. In G_1, a newly formed cell makes materials needed for cell growth. In the S stage, DNA is replicated. At this stage, DNA consists of long, thin strands called chromatin. As each strand is replicated, it is linked to its duplicate by a structure known as a centromere.

In prophase the replicated, linked DNA strands slowly wrap around proteins that in turn coil and condense into two structures called chromatids, attached by the centromere. Two structures called centrioles, both located on one side of the nucleus, separate and move toward opposite poles of the cell. As the centrioles move apart, they begin to radiate thin, hollow, proteins called microtubules. The microtubules arrange themselves in the shape of a football, or spindle, that spans the cell, with the widest part at the center of the cell and the narrower ends at opposite poles. As the spindle forms, the nuclear membrane breaks down into tiny sacs or vesicles that are dispersed in the cytoplasm.

In metaphase, the spindle fibers attach to the chromatids near the centromeres, and tug and push the chromatids so that they line up in the equatorial plane of the cell halfway between the poles. Like two individuals standing back to back at the equator, one chromatid faces one pole of the cell, and its linked partner faces the opposite pole.

Anaphase begins when the centromeres split, separating the identical chromatids into single chromosomes, which then move along the spindle fibers to opposite poles of the cell.

As these two identical groups of single chromosomes gather at opposite poles of the cell, telophase begins. A new nuclear membrane forms around each new group of chromosomes. The spindle fibers break down and the newly formed chromosomes begin to unwind.

The final phase of the cell cycle is known as cytokinesis. In cytokinesis, the cell's cytoplasm separates in half, with each half containing one nucleus. Animals and plants accomplish cytokinesis in slightly different ways. In animals, the cell membrane pinches in, creating a cleavage furrow, until the mother cell is pinched in half. In plants, cellulose and other materials that make up the cell wall are transported to the midline of the cell and a new cell wall is constructed. The process of DNA replication, the precise alignment of the chromosomes in mitosis, and the successful separation of identical chromatids in anaphase results in two new cells that are genetically identical. The new cells enter interphase, and the cell cycle begins again.

Meiosis

Prior to meiosis, the cell undergoes interphase, in which it synthesizes materials needed for cell growth and prepares for cell division. During this stage, the cell's genetic information, in the form of deoxyribonucleic acid (DNA), is replicated. Each of the two consecutive cell divisions consists of four stages: prophase, metaphase, anaphase, and telophase.

In prophase I each long DNA strand wraps around proteins that in turn coil and condense to form a chromosome. Since the DNA was copied during interphase, each chromosome condenses to form two identical chromatids, joined at a centromere. A corn cell has 20 chromosomes at this stage, each with two identical chromatids, making 40 chromatids.

Chromosomes exist in pairs; one is inherited from the mother (maternal) and one from the father (paternal). When the chromosomes duplicate, two maternal and two paternal chromatids are produced. These two pairs of chromatids gather in groups of four called tetrads. While grouped together in tetrads, sections of the chromatids from the maternal pair may randomly exchange, or cross over, with sections of the paternal chromatid pair. Called genetic recombination, this process is the first of two ways that meiosis mixes genetic information during sexual reproduction.

Also in prophase I, two structures called centrioles, both located on one side of the nucleus, separate and move toward opposite sides of the cell. As the centrioles move apart, they radiate thin hollow structures called spindle fibers. The membrane around the nucleus of

	the cell breaks down, marking the beginning of the next stage. During metaphase I, the spindle fibers attach to the chromatids near the centrioles. The spindle fibers move the tetrads so that they line up in a plane halfway between two centrioles. Anaphase I begins when the spindle fibers pull the tetrads apart, pulling the maternal and paternal chromosomes toward opposite sides of the cell. The first meiotic division concludes with telophase I, when the two new groups of chromosomes reach opposite sides of the cell. A nuclear membrane may form around the two new groups of chromosomes and a division of cell cytoplasm forms two new daughter cells. Each daughter cell receives 10 chromosomes made up of a random mixture of maternal and paternal chromosomes. This second mixing of genetic information is called independent assortment. Genetic recombination and independent assortment make it possible for parents to have many offspring who are all different from each other. In the second meiotic division the cell moves directly into prophase II, skipping the interphase replication of DNA. Each corn cell begins the second division with 10 chromosomes. Once again the centrioles radiate spindle fibers as they move to opposite sides of the cell. During metaphase II, the chromosomes line up along the plane in the center of the cell, and in anaphase II the pairs of chromatids are pulled apart, each moving toward opposite ends of the cell. Telophase II completes meiosis. The spindle fibers disappear and a new nuclear membrane forms around each new group of chromosomes to form four haploid cells. The original diploid corn cell with 20 chromosomes has undergone meiosis to form four haploid daughter cells, each containing 10 chromatids. It is now possible for two haploid sex cells to join during fertilization to form one egg cell with the normal diploid number of chromatids.
Differences	Meiosis differs from normal cell division, or mitosis, in that it involves two consecutive cell divisions instead of one and the genetic material contained in chromosomes is not copied during the second meiotic division. Whereas mitosis produces identical daughter cells, meiosis randomly mixes the chromosomes, resulting in unique combinations of chromosomes in each daughter cell.

II. Classification	
Scientific name	Binomial nomenclature.
Hierarchical list of groups	Kingdom, Phylum, Class, Order, Family, Genus, Species, Sub–Species
Linnaeus	He was a Swedish naturalist, who developed binomial nomenclature to classify and organize plants and animals.
Dichotomous key	A key for the identification of organisms based on a series of choices between alternative characters
Binomial nomenclature	A name consisting of a genus and a species. *i.e. Homo Sapiens*
Phylogeny	The development over time of a species, genus, or group.
Biosystematics	The study of the relationships among groups of species using criteria such as morphology, biochemistry, and DNA comparisons, especially to determine the history of a species.
Kingdoms	Archaebacteria – Oldest form of life on earth, anaerobic. *i.e. Methanogens, halobacteria* Eubacteria – 'True Bacteria', more complex than archaebacteria. *i.e. e.coli, Salmonella, Rickettsia* Fungi – Nonphotosynthetic multicellular organisms that digest food externally *i.e. mushrooms* Protista – Unicellular eukaryotes, algae *i.e. algae*

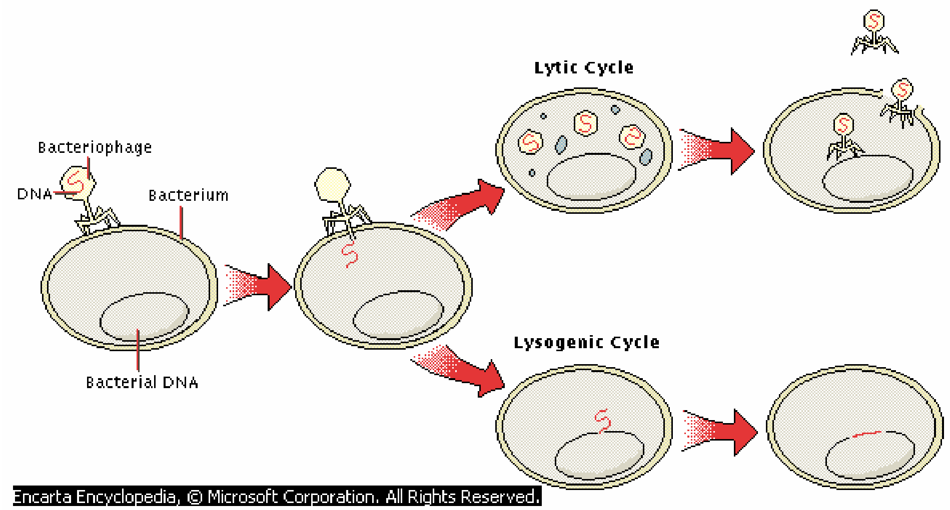
	Plantae – Terrestrial photosynthetic multicellular organisms *i.e. flowers* Animalia – Nonphotosynthetic multicellular organisms that digest food internally *i.e. Homo Sapiens*
Classification evidence	Biological Species Concept – Interbreeding natural populations which are reproductively isolated from other groups Morphological Species Concept – Classification based on morphology, or outward characteristics

III. Evolution	
Lamarck's ideas	Three biological laws: environmental influence on organ development, change in body structure based on use and disuse of parts, and the inheritance of acquired characteristics.
Darwin's ideas	Natural selection – survival of the fittest, inheritance of genes
Sexual reproduction advantages	One might receive advantageous characteristics that enable it to survive better than those who do not. They will survive to reproduce, which will eventually lead to a stronger population.
Natural selection	'Survival of the fittest' – Only the ones suited to the environment the best will survive.
Radioactive isotopes	An isotope of an element that emits energy in the form of streams of particles, owing to the decaying of its unstable atoms. Used in dating; C_{14} will decay into C_{12}. C_{12}'s half–life is 5730 years. This limits the dating method to about 50000 years. Potassium–Argon method – Used to date rocks. Half life is 1.2 billion years. Rubidium–Strontium method – beta decay of $Rubidium_{87}$ to $Strontium_{87}$. Used to check Potassium Argon method.
Adaptive radiation	The developmental diversification of a group of organisms from an original ancestral form or group into several different forms that adapt to different environments.
Fossil record	Fossils of species embedded in old rock are different than fossils in newer rocks.
Homologous structures	Structure and function might be diverged; but derived from the same body part in a common ancestor
Analogous structures	Structures that come to resemble each other because of parallel evolution of separate lineages.
Geographic isolation	Species occur in different areas, which are often separated by a physical barrier.
Punctuated equilibrium	Fossil record will be very discontinuous, 'jerky'
Species	A basic biological classification and containing individuals that resemble one another and that may interbreed.
Genetic drift	The random changes that occur in the gene frequency of small, isolated populations, resulting in the loss or preservation of certain genes over the generations.
Immigration	Movement into a population
Emigration	Movement out of a population
Disruptive selection	Deaths are concentrated in the middle of the range of phenotypes. The extreme forms of the trait are favored.
Reproductive isolation	Hybrids produced by new species breeding with each other are ill–suited to either environment

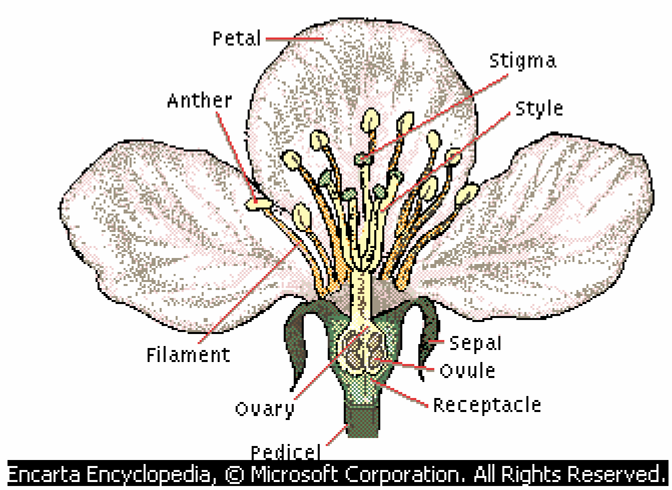
Convergent evolution	Evolution of species that gradually resemble each other, even though there is no common ancestor.
Divergent evolution	Evolution that begins with a common ancestor.
Co–evolution	Parallel evolution of two species in an area.
Vestigial	Leftover
Competition	The struggle between organisms of the same or different species for limited resources such as food or light.
Half–life	The amount of years for half of a radioactive isotope to decay.
Speciation	Formation of new species

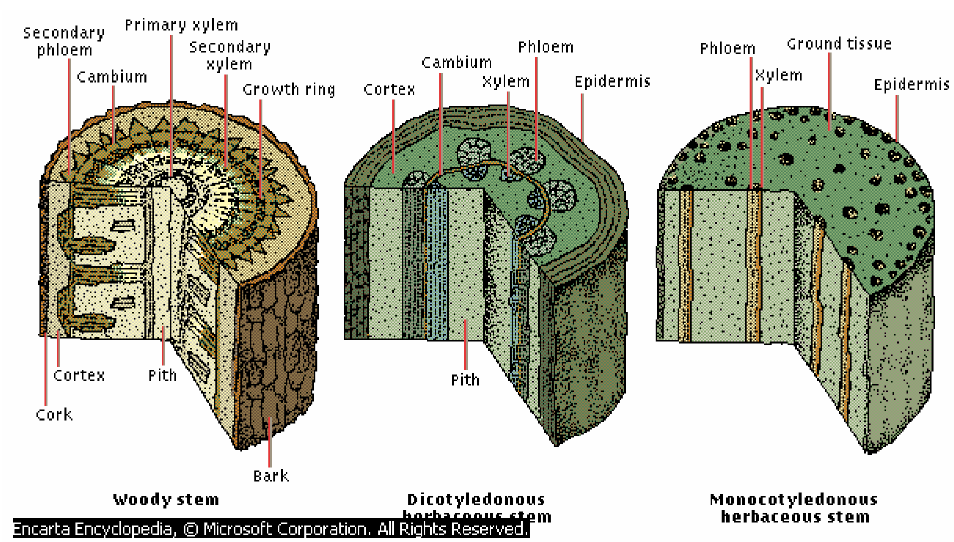
IV. Bacteria and Viruses

Structure of bacteria	No nucleus, no organelle membranes, rigid cell wall, loop of DNA.
Gram–positive/negative	Absence or presence of popolysaccharide, respectively. Tells scientists about bacteria's resistance to antibiotics that attack bacterial cell wall.
Shapes	Rod–shaped (bacillus), Spherical (coccus), Spiral (spirillus)
Reproduction	Binary fission – increase in size, divide in two Conjugation – passing of plasmids
Prokaryotes vs. Eukaryotes	Internal compartmentalization – very little internal organization Cell size – prokaryotes are small Unicellularity – bacteria are fundamentally single celled Chromosomes – bacteria do not have chromosomes Cell division – binary fission instead of mitosis Flagella – Single fiber of protein instead of 9+2 arrangement of microtubules Metabolic diversity – bacteria have many metabolic abilities that eukaryotes do not.
Archeabacteria	Oldest form of life in earth; anaerobic, unusual cell walls
Eubacteria	'True bacteria', almost all of bacteria, have peptidoglycan cell walls, no introns
Methanogens	Turns carbon dioxide into methane, obligate anaerobes
Thermoacidophiles	Favor hot, acidic springs such as sulfur springs of Yellowstone
Cyanobacteria	Photosynthetic bacteria, some cells do nitrogen fixation
Heterocysts	Specialized cells that do nitrogen fixation in cyanobacteria
Chemoautotrophs	Able to obtain energy from inorganic chemicals
Obligate, facultative anaerobes	Obligate – must be without oxygen Facultative – able to live in or out of oxygen
Antibiotics	Drugs that kill bacteria; some destroy cell walls, others attack inside of bacteria
Endotoxins	Toxins that are released only when bacteria disintegrate
Exotoxins	Toxins that are regularly released
Types of bacterial diseases	Cholera, diptheria, leprosy, Lyme disease, plague, tuberculosis, typhus
Structure of viruses	Core of nucleic acid surrounded by protein

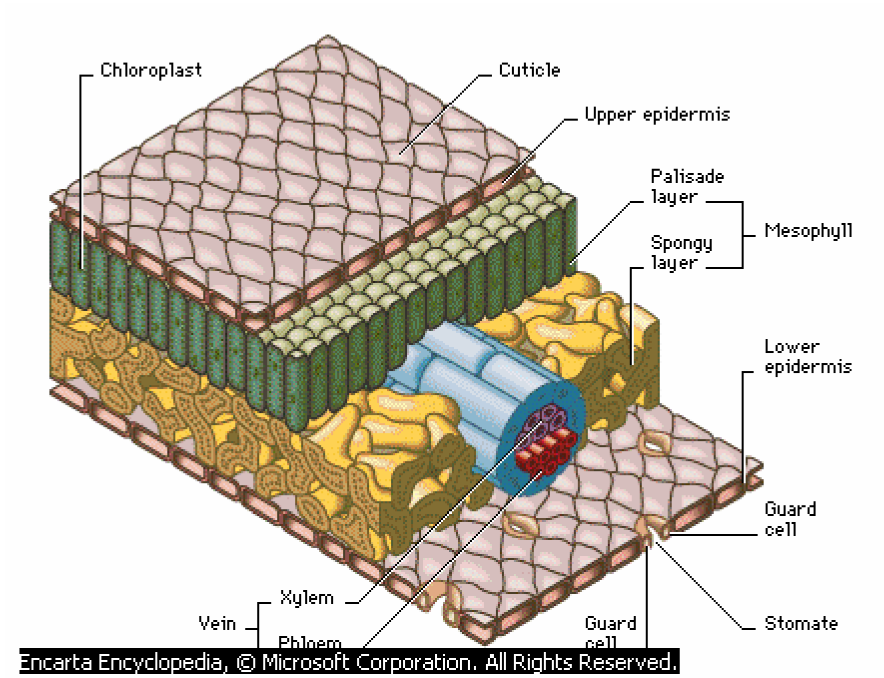
How viruses get into cells	Induced endocytosis, injection of DNA
How viruses cause disease	They destroy cells
Lytic/Lysogenic cycle	
Reverse transcriptase	Makes DNA complementary to viral RNA
Types of viral diseases	AIDS, Ebola, Hepatitis B, influenza, polio, yellow fever

V. Plants

Alternation of generation	Two generations in plants – gametophyte (*n*), sporophyte (*2n*). The gametophyte sexually reproduces, while the sporophyte reproduces asexually. Ferns have dominant sporophyte generations, while mosses have dominant gametophyte generations.
Parts of a flower	
Parts of a seed	A seed has three main parts. The embryo consists of the cells that will develop into the structures of the adult plant (root, bud, stalk, and leaf). The cotyledons—one in monocots and gymnosperms and two in dicots—are organs of absorption, drawing food from the seed's storage tissue. In monocots, this tissue is called the endosperm, and in gymnosperms, the megagametophyte. The cotyledons themselves serve as storage tissue in

	dicots. The seed coat protects all of these structures from predation, injury, and moisture loss.
Pollination	The pollen reaches the ovary, and fertilizes the egg. This occurs in different ways in different types of plants. In mosses, pollen is formed in the antheridium and drifts onto the archegonium. In ferns, both the archegonium and the antheridium are on the gametophyte.
Double Fertilization	Pollen grains are made of a generative cell and a tube cell. The tube cell drills a pollen tube, and the generative cell changes into two sperms. The sperm travels down the pollen tube into the ovary, where double fertilization occurs. One sperm fertilizes the egg, while the other unites with the polar nuclei to form an triploid endosperm cell. This happens only in angiosperms.
Pollen (microgametophyte) formation	The pollen is formed in antheridia in seedless plants. There are two types of seeded plants: gymnosperms, and angiosperms. In gymnosperms, the pollen is formed in pollen–bearing cones. These cones include pollen mother cells in their scales. Meiosis occurs in the mother cells ($2n$), forming microspores (n), which further chance into pollen (n). In angiosperms, the pollen is formed in the anther. Meiosis also occurs in the diploid pollen mother cells, forming pollen grains. These pollen grains have two parts: the generative cell, and the tube cell.
Egg (megagametophyte) formation	In seedless plants, the eggs are formed in archegonia. In gymnosperms, the eggs are formed out of a megaspore mother cell. It divides into four cells, three of which die. The one left is the megaspore, which changes into two ovules. In angiosperms, the process takes place in the ovary. The monoploid megaspore divides into a 8–nucleate embryo sac (n). This changes into the egg: three cells are on the top; two polar nuclei are in the middle; and two cells surrounding an egg are on the bottom.
Bryophytes/Tracheophyes	Bryophyte: a nonflowering plant, often growing in damp places, that has separate gamete-bearing and spore-bearing forms. Mosses are bryophytes. Tracheophyte: a plant that has a system of vascular tissues for conducting water and nutrients through it.
Vascular/Non–vascular	Vascular: specialized strands of hollow cells connected end to end like a pipeline; consist of xylem (water–conducting) and phloem (nutrient–conducting) tissue. Non–vascular: cannot grow very tall, must live in moist habitats, obtain nutrients and water by diffusion.
Stem and root cells	

Leaf parts



Functions of cell types	**Meristems** – Major growth zones. Apical meristems initiate primary growth at the tips. Secondary growth, or growth in thickness, happens in the lateral meristems. In woody stems, vascular cambium gives rise to accumulations of secondary xylem and phloem, and cork cambium gives rise to bark. **Ground tissue** – Parenchyma: most common cells Collenchyma: strands or continuous cylinders beneath epidermis. Provides support for plant organs in which secondary growth has not occurred Sclerenchyma: do not contain living cytoplasm, two types: fibers and sclereids. They strengthen the tissues. **Dermal tissue** – Cuticle, epidermis, guard cells, stomata, trichomes **Vascular tissue** – Xylem: water conducting Phloem: nutrient conducting
Liverworts, mosses, and ferns	They have no vascular system, and are often very low. They are bryophytes.
Gametophyte/sporophyte	The gametophyte generation is monoploid, while the sporophyte generation is diploid.
Angiosperms	They are the flowering plants. They are the most common.
Gymnosperms	They are the first plants to evolve seeds. There are four kinds: conifers, cycads, ginkgoes, and gnetophytes. They have no flowers.
Fruits	They help to disperse seeds.

VI. Genetics

Crosses

i.e. (from fruit flies report)

$X^{EW}YBb \times X^{EW}X^{ew}Bb$

$\frac{1}{4}\ X^{EW}B + \frac{1}{4}\ X^{EW}b + \frac{1}{4}\ YB + \frac{1}{4}\ Yb$

$\frac{1}{4}\ X^{EW}B + \frac{1}{4}\ X^{EW}b + \frac{1}{4}\ X^{ew}B + \frac{1}{4}\ X^{ew}b$

$\frac{1}{16}$ $X^{EW}X^{EW}BB$ + $\frac{1}{16}$ $X^{EW}X^{EW}Bb$ + $\frac{1}{16}$ $X^{EW}YBB$ + $\frac{1}{16}$ $X^{EW}Ybb$ + $\frac{1}{16}$ $X^{EW}X^{EW}Bb$ + $\frac{1}{16}$ $X^{EW}X^{EW}bb$ + $\frac{1}{16}$ $X^{EW}Ybb$ + $\frac{1}{16}$ $X^{EW}Ybb$ + $\frac{1}{16}$ $X^{EW}X^{ew}BB$ + $\frac{1}{16}$ $X^{EW}X^{ew}Bb$ + $\frac{1}{16}$ $X^{ew}YBB$ + $\frac{1}{16}$ $X^{ew}Ybb$ + $\frac{1}{16}$ $X^{EW}X^{ew}Bb$ + $\frac{1}{16}$ $X^{EW}X^{ew}bb$ + $\frac{1}{16}$ $X^{ew}YBb$ + $\frac{1}{16}$ $X^{ew}Ybb$.

Which is:

$\frac{1}{8}$ $X^{EW}X^{EW}Bb$	$\frac{3}{16}$ $X^{EW}Ybb$
$\frac{1}{8}$ $X^{EW}X^{ew}Bb$	$\frac{1}{8}$ $X^{ew}Ybb$
$\frac{1}{16}$ $X^{EW}X^{EW}BB$	$\frac{1}{16}$ $X^{EW}YBB$
$\frac{1}{16}$ $X^{EW}X^{EW}bb$	$\frac{1}{16}$ $X^{ew}YBB$
$\frac{1}{16}$ $X^{EW}X^{ew}BB$	$\frac{1}{16}$ $X^{ew}YBb$
$\frac{1}{16}$ $X^{EW}X^{ew}bb$	

Sex linked traits	If the mother has a recessive trait, the son will have it too. If a daughter has a recessive trait, it implies that the father has it too.
Rules of probability	Sum rule – mutually exclusive events: add probabilities Product rule – event following an event; simultaneously: multiply probabilities
Hardy Weinberg	$P + Q = 1$ $P^2 + 2PQ + Q^2 = 1$ Q^2 is the probability of the recessive trait in a population. You can derive P^2 and $2PQ$ by: $P^2 = \left(1 - \sqrt{Q_2}\right)^2$ $2PQ = 1 - P^2 - Q^2$

VII. Systems

Digestive	*Enzymes in the digestive system* Mouth: Ptyalin (salivary amylase) Stomach: Pepsin Pancreas: Hydrolases (trypsin, chymotrypsin) – digest polypeptides; lipases; pancreatic amylase; ribonuclease, deoxyribonuclease (degenerates RNA, DNA) If a human adult's digestive tract were stretched out, it would be 6 to 9 m (20 to 30 ft) long. In humans, digestion begins in the mouth, where both mechanical and chemical digestion occur. The mouth quickly converts food into a soft, moist mass. The muscular tongue pushes the food against the teeth, which cut, chop, and grind the food. Glands in the cheek linings secrete mucus, which lubricates the food, making it easier to chew and swallow. Three pairs of glands empty saliva into the mouth through ducts to moisten the food. Saliva contains the enzyme ptyalin, which begins to hydrolyze (break down) starch—a carbohydrate manufactured by green plants. Once food has been reduced to a soft mass, it is ready to be swallowed. The tongue pushes this mass—called a bolus—to the back of the mouth and into the pharynx. This cavity between the mouth and windpipe serves as a passageway both for food on its way down the alimentary canal and for air passing into the windpipe. The epiglottis, a flap of cartilage, covers the trachea (windpipe) when a person swallows. This action of the epiglottis prevents choking by directing food from the windpipe and toward the stomach. The presence of food in the pharynx stimulates swallowing, which squeezes the food into the esophagus. The esophagus, a muscular tube about 25 cm (10 in) long, passes behind the trachea and heart and penetrates the diaphragm (muscular wall between the chest and

abdomen) before reaching the stomach. Food advances through the alimentary canal by means of rhythmic muscle contractions (tightenings) known as peristalsis. The process begins when circular muscles in the esophagus wall contract and relax (widen) one after the other, squeezing food downward toward the stomach. Food travels the length of the esophagus in two to three seconds.

A circular muscle called the esophageal sphincter separates the esophagus and the stomach. As food is swallowed, this muscle relaxes, forming an opening through which the food can pass into the stomach. Then the muscle contracts, closing the opening to prevent food from moving back into the esophagus. The esophageal sphincter is the first of several such muscles along the alimentary canal. These muscles act as valves to regulate the passage of food and keep it from moving backward.

The stomach, located in the upper abdomen just below the diaphragm, is a saclike structure with strong, muscular walls. The stomach can expand significantly to store all the food from a meal for both mechanical and chemical processing. The stomach contracts about three times per minute, churning the food and mixing it with gastric juice. This fluid, secreted by thousands of gastric glands in the lining of the stomach, consists of water, hydrochloric acid, an enzyme called pepsin, and mucin (the main component of mucus). Hydrochloric acid creates the acidic environment that pepsin needs to begin breaking down proteins. It also kills microorganisms that may have been ingested in the food. Mucin coats the stomach, protecting it from the effects of the acid and pepsin. About four hours or less after a meal, food processed by the stomach, called chyme, begins passing a little at a time through the pyloric sphincter into the duodenum, the first portion of the small intestine.

Most digestion, as well as absorption of digested food, occurs in the small intestine. This narrow, twisting tube, about 2.5 cm (1 in) in diameter, fills most of the lower abdomen, extending about 6 m (20 ft) in length. Over a period of three to six hours, peristalsis moves chyme through the duodenum into the next portion of the small intestine, the jejunum, and finally into the ileum, the last section of the small intestine. During this time, the liver secretes bile into the small intestine through the bile duct. Bile breaks large fat globules into small droplets, which enzymes in the small intestine can act upon. Pancreatic juice, secreted by the pancreas, enters the small intestine through the pancreatic duct. Pancreatic juice contains enzymes that break down sugars and starches into simple sugars, fats into fatty acids and glycerol, and proteins into amino acids. Glands in the intestinal walls secrete additional enzymes that break down starches and complex sugars into nutrients that the intestine absorbs. Structures called Brunner's glands secrete mucus to protect the intestinal walls from the acid effects of digestive juices.

The small intestine's capacity for absorption is increased by millions of fingerlike projections called villi, which line the inner walls of the small intestine. Each villus is about 0.5 to 1.5 mm (0.02 to 0.06 in) long and covered with a single layer of cells. Even tinier fingerlike projections called microvilli cover the cell surfaces. This combination of villi and microvilli increases the surface area of the small intestine's lining by about 150 times, multiplying its capacity for absorption. Beneath the villi's single layer of cells are capillaries (tiny vessels) of the bloodstream and the lymphatic system. These capillaries allow nutrients produced by digestion to travel to the cells of the body. Simple sugars and amino acids pass through the capillaries to enter the bloodstream. Fatty acids and glycerol pass through to the lymphatic system.

A watery residue of indigestible food and digestive juices remains unabsorbed. This residue leaves the ileum of the small intestine and moves by peristalsis into the large intestine, where it spends 12 to 24 hours. The large intestine forms an inverted U over the coils of the small intestine. It starts on the lower right-hand side of the body and ends on the lower left-hand side. The large intestine is 1.5 to 1.8 m (5 to 6 ft) long and about 6 cm (2.5 in) in diameter.

The large intestine serves several important functions. It absorbs water—about 6 liters (1.6 gallons) daily—as well as dissolved salts from the residue passed on by the small intestine. In addition, bacteria in the large intestine promote the breakdown of undigested materials and make several vitamins, notably vitamin K, which the body needs for blood clotting. The large intestine moves its remaining contents toward the rectum, which makes up the final 15 to 20 cm (6 to 8 in) of the alimentary canal. The rectum stores the feces—waste

	material that consists largely of undigested food, digestive juices, bacteria, and mucus—until elimination. Then, muscle contractions in the walls of the rectum push the feces toward the anus. When sphincters between the rectum and anus relax, the feces pass out of the body.
Circulatory	The heart ejects oxygen-rich blood under high pressure out of the heart's main pumping chamber, the left ventricle, through the largest artery, the aorta. Smaller arteries branch off from the aorta, leading to various parts of the body. These smaller arteries in turn branch out into even smaller arteries, called arterioles. Branches of arterioles become progressively smaller in diameter, eventually forming the capillaries. Once blood reaches the capillary level, blood pressure is greatly reduced. Capillaries have extremely thin walls that permit dissolved oxygen and nutrients from the blood to diffuse across to a fluid, known as interstitial fluid, that fills the gaps between the cells of tissues or organs. The dissolved oxygen and nutrients then enter the cells from the interstitial fluid by diffusion across the cell membranes. Meanwhile, carbon dioxide and other wastes leave the cell, diffuse through the interstitial fluid, cross the capillary walls, and enter the blood. In this way, the blood delivers nutrients and removes wastes without leaving the capillary tube. After delivering oxygen to tissues and absorbing wastes, the deoxygenated blood in the capillaries then starts the return trip to the heart. The capillaries merge to form tiny veins, called venules. These veins in turn join together to form progressively larger veins. Ultimately, the veins converge into two large veins: the inferior vena cava, bringing blood from the lower half of the body; and the superior vena cava, bringing blood from the upper half. Both of these two large veins join at the right atrium of the heart. Because the pressure is dissipated in the arterioles and capillaries, blood in veins flows back to the heart at very low pressure, often running uphill when a person is standing. Flow against gravity is made possible by the one-way valves, located several centimeters apart, in the veins. When surrounding muscles contract, for example in the calf or arm, the muscles squeeze blood back toward the heart. If the one-way valves work properly, blood travels only toward the heart and cannot lapse backward. Veins with defective valves, which allow the blood to flow backward, become enlarged or dilated to form varicose veins. A single blood cell takes roughly 30 seconds to complete a full circuit through both the pulmonary and systemic circulation. In pulmonary circulation, deoxygenated blood returning from the organs and tissues of the body travels from the right atrium of the heart to the right ventricle. From there it is pushed through the pulmonary artery to the lung. In the lung, the pulmonary artery divides, forming the pulmonary capillary region of the lung. At this site, microscopic vessels pass adjacent to the alveoli, or air sacs of the lung, and gases are exchanged across a thin membrane: oxygen crosses the membrane into the blood while carbon dioxide leaves the blood through this same membrane. Newly oxygenated blood then flows into the pulmonary veins, where it is collected by the left atrium of the heart, a chamber that serves as collecting pool for the left ventricle. The contraction of the left ventricle sends blood into the aorta, completing the circulatory loop. On average, a single blood cell takes roughly 30 seconds to complete a full circuit through both the pulmonary and systemic circulation. In addition to oxygen, the circulatory system also transports nutrients derived from digested food to the body. These nutrients enter the bloodstream by passing through the walls of the intestine. The nutrients are absorbed through a network of capillaries and veins that drain the intestines, called the hepatic portal circulation. The hepatic portal circulation carries the nutrients to the liver for further metabolic processing. The liver stores a variety of substances, such as sugars, fats, and vitamins, and releases these to the blood as needed. The liver also cleans the blood by removing waste products and toxins. After hepatic portal blood has crossed the liver cells, veins converge to form the large hepatic vein that joins the vena cava near the right atrium. The circulatory system plays an important role in regulating body temperature. During exercise, working muscles generate heat. The blood supplying the muscles with oxygen and nutrients absorbs much of this heat and carries it away to other parts of the body. If the body gets too warm, blood vessels near the skin enlarge to disperse excess heat outward through the skin. In cold environments, these blood vessels constrict to retain heat.

	The circulatory system works in tandem with the endocrine system, a collection of hormone-producing glands. These glands release chemical messengers, called hormones, directly into the bloodstream to be transported to specific organs and tissues. Once they reach their target destination, hormones regulate the body's rate of metabolism, growth, sexual development, and other functions. The circulatory system also works with the immune system and the coagulation system. The immune system is a complex system of many types of cells that work together to combat diseases and infections. Disease-fighting white blood cells and antibodies circulate in the blood and are transported to sites of infection by the circulatory system. The coagulation system is composed of special blood cells, called platelets, and special proteins, called clotting factors, that circulate in the blood. Whenever blood vessels are cut or torn, the coagulation system works rapidly to stop the bleeding by forming clots. Other organs support the circulatory system. The brain and other parts of the nervous system constantly monitor blood circulation, sending signals to the heart or blood vessels to maintain constant blood pressure. New blood cells are manufactured in the bone marrow. Old blood cells are broken down in the spleen, where valuable constituents, such as iron, are recycled. Metabolic waste products are removed from the blood by the kidneys, which also screen the blood for excess salt and maintain blood pressure and the body's balance of minerals and fluids. The pressure generated by the pumping action of the heart propels the blood to the arteries. In order to maintain an adequate flow of blood to all parts of the body, a certain level of blood pressure is needed. Blood pressure, for instance, enables a person to rise quickly from a horizontal position without blood pooling in the legs, which would cause fainting from deprivation of blood to the brain. Normal blood pressure is regulated by a number of factors, such as the contraction of the heart, the elasticity of arterial walls, blood volume, and resistance of blood vessels to the passage of blood. Blood pressure is measured using an inflatable device with a gauge called a sphygmomanometer that is wrapped around the upper arm. Blood pressure is measured during systole, the active pumping phase of the heart, and diastole, the resting phase between heartbeats. Systolic and diastolic pressures are measured in units of millimeters of mercury (abbreviated mm Hg) and displayed as a ratio. Blood pressure varies between individuals and even during the normal course of a day in response to emotion, exertion, sleep, and other physical and mental changes. The average normal blood pressure is about 120/80 mm Hg. Higher blood pressures that are sustained over a long period of time may indicate hypertension, a damaging circulatory condition. Lower blood pressures could signal shock from heart failure, dehydration, internal bleeding, or blood loss.
Respiratory	The organs of the respiratory system extend from the nose to the lungs and are divided into the upper and lower respiratory tracts. The upper respiratory tract consists of the nose and the pharynx, or throat. The lower respiratory tract includes the larynx, or voice box; the trachea, or windpipe, which splits into two main branches called bronchi; tiny branches of the bronchi called bronchioles; and the lungs, a pair of saclike, spongy organs. The nose, pharynx, larynx, trachea, bronchi, and bronchioles conduct air to and from the lungs. The lungs interact with the circulatory system to deliver oxygen and remove carbon dioxide. The flow of air from outside of the body to the lungs begins with the nose, which is divided into the left and right nasal passages. The nasal passages are lined with a membrane composed primarily of one layer of flat, closely packed cells called epithelial cells. Each epithelial cell is densely fringed with thousands of microscopic cilia, fingerlike extensions of the cells. Interspersed among the epithelial cells are goblet cells, specialized cells that produce mucus, a sticky, thick, moist fluid that coats the epithelial cells and the cilia. Numerous tiny blood vessels called capillaries lie just under the mucous membrane, near the surface of the nasal passages. While transporting air to the pharynx, the nasal passages play two critical roles: they filter the air to remove potentially disease-causing particles; and they moisten and warm the air to protect the structures in the respiratory system. Filtering prevents airborne bacteria, viruses, other potentially disease-causing substances from entering the lungs, where they may cause infection. Filtering also eliminates smog and dust particles, which may clog the narrow air passages in the smallest bronchioles. Coarse hairs found just inside the nostrils of the nose trap airborne particles as they are

inhaled. The particles drop down onto the mucous membrane lining the nasal passages. The cilia embedded in the mucous membrane wave constantly, creating a current of mucus that propels the particles out of the nose or downward to the pharynx. In the pharynx, the mucus is swallowed and passed to the stomach, where the particles are destroyed by stomach acid. If more particles are in the nasal passages than the cilia can handle, the particles build up on the mucus and irritate the membrane beneath it. This irritation triggers a reflex that produces a sneeze to get rid of the polluted air.

Air leaves the nasal passages and flows to the pharynx, a short, funnel-shaped tube about 13 cm (5 in) long that transports air to the larynx. Like the nasal passages, the pharynx is lined with a protective mucous membrane and ciliated cells that remove impurities from the air. In addition to serving as an air passage, the pharynx houses the tonsils, lymphatic tissues that contain white blood cells. The white blood cells attack any disease-causing organisms that escape the hairs, cilia, and mucus of the nasal passages and pharynx.

Air moves from the pharynx to the larynx, a structure about 5 cm (2 in) long located approximately in the middle of the neck. Several layers of cartilage, a tough and flexible tissue, comprise most of the larynx.

While the primary role of the larynx is to transport air to the trachea, it also serves other functions. It plays a primary role in producing sound; it prevents food and fluid from entering the air passage to cause choking; and its mucous membranes and cilia-bearing cells help filter air. The cilia in the larynx waft airborne particles up toward the pharynx to be swallowed.

Food and fluids from the pharynx usually are prevented from entering the larynx by the epiglottis, a thin, leaflike tissue. The “stem” of the leaf attaches to the front and top of the larynx. When a person is breathing, the epiglottis is held in a vertical position, like an open trap door. When a person swallows, however, a reflex causes the larynx and the epiglottis to move toward each other, forming a protective seal, and food and fluids are routed to the esophagus.

Air passes from the larynx into the trachea, a tube about 12 to 15 cm (about 5 to 6 in) long located just below the larynx. The trachea is formed of 15 to 20 C-shaped rings of cartilage. The sturdy cartilage rings hold the trachea open, enabling air to pass freely at all times. The open part of the C-shaped cartilage lies at the back of the trachea, and the ends of the “C” are connected by muscle tissue.

The base of the trachea is located a little below where the neck meets the trunk of the body. Here the trachea branches into two tubes, the left and right bronchi, which deliver air to the left and right lungs, respectively. Within the lungs, the bronchi branch into smaller tubes called bronchioles. The trachea, bronchi, and the first few bronchioles contribute to the cleansing function of the respiratory system, for they, too, are lined with mucous membranes and ciliated cells that move mucus upward to the pharynx.

The bronchioles divide many more times in the lungs to create an impressive tree with smaller and smaller branches, some no larger than 0.5 mm (0.02 in) in diameter. These branches dead-end into tiny air sacs called alveoli. The alveoli deliver oxygen to the circulatory system and remove carbon dioxide. Interspersed among the alveoli are numerous macrophages, large white blood cells that patrol the alveoli and remove foreign substances that have not been filtered out earlier. The macrophages are the last line of defense of the respiratory system; their presence helps ensure that the alveoli are protected from infection so that they can carry out their vital role.

The alveoli number about 150 million per lung and comprise most of the lung tissue. Alveoli resemble tiny, collapsed balloons with thin elastic walls that expand as air flows into them and collapse when the air is exhaled. Alveoli are arranged in grapelike clusters, and each cluster is surrounded by a dense hairnet of tiny, thin-walled capillaries. The alveoli and capillaries are arranged in such a way that air in the wall of the alveoli is only about 0.1 to 0.2 microns from the blood in the capillary. Since the concentration of oxygen is much higher in the alveoli than in the capillaries, the oxygen diffuses from the alveoli to the capillaries. The oxygen flows through the capillaries to larger vessels, which carry the oxygenated blood to the heart, where it is pumped to the rest of the body.

Carbon dioxide that has been dumped into the bloodstream as a waste product from cells throughout the body flows through the bloodstream to the heart, and then to the alveolar capillaries. The concentration of carbon dioxide in the capillaries is much higher than in

	the alveoli, causing carbon dioxide to diffuse into the alveoli. Exhalation forces the carbon dioxide back through the respiratory passages and then to the outside of the body. The flow of air in and out of the lungs is controlled by the nervous system, which ensures that humans breathe in a regular pattern and at a regular rate. Breathing is carried out day and night by an unconscious process. It begins with a cluster of nerve cells in the brain stem called the respiratory center. These cells send simultaneous signals to the diaphragm and rib muscles, the muscles involved in inhalation. The diaphragm is a large, dome-shaped muscle that lies just under the lungs. When the diaphragm is stimulated by a nervous impulse, it flattens. The downward movement of the diaphragm expands the volume of the cavity that contains the lungs, the thoracic cavity. When the rib muscles are stimulated, they also contract, pulling the rib cage up and out like the handle of a pail. This movement also expands the thoracic cavity. The increased volume of the thoracic cavity causes air to rush into the lungs. The nervous stimulation is brief, and when it ceases, the diaphragm and rib muscles relax and exhalation occurs. Under normal conditions, the respiratory center emits signals 12 to 20 times a minute, causing a person to take 12 to 20 breaths a minute. Newborns breathe at a faster rate, about 30 to 50 breaths a minute.
Excretory	The kidneys lie embedded in fat tissue on either side of the backbone at about waist level. Each fist-sized kidney is reddish-brown, weighs 140 to 160 g (5 to 6 oz), and is similar in shape to the kidney beans sold at the supermarket. On the inner border of each kidney is a depression called the hilum, where the renal artery, the renal vein, and the ureter connect with the kidney (the adjective renal is from the Latin term renalis, meaning of or near the kidneys). The renal artery delivers over 1700 liters (450 gal) of blood to the kidneys each day, which these organs filter and return to the heart via the renal vein. Each kidney contains about 1 million microscopic coiled channels, called nephrons, which perform this critical blood-filtering function and produce urine in the process. The bulblike upper portion of the kidney's nephrons filters water; urea, the nitrogen-containing breakdown product of protein; salts; glucose; amino acids, the building blocks of proteins; yellow bile compounds from the liver; and other trace substances from the blood. As this material moves through a long, looped tubule, many of these filtered materials are reabsorbed into the blood to be reused by the body to maintain normal body functions. Less than 1 percent of the water and other materials remain behind to be excreted as waste products in the urine. These waste materials then pass from the nephrons into a funnel-shaped area called the renal pelvis. From the renal pelvis, waste trickles out of the kidney into the ureter, which is about 25 to 30 cm (10 to 12 in) long and about 0.5 cm (0.2 in) in diameter. The ureter empties into a hollow, muscular sac called the urinary bladder. A valvelike flap of tissue at the point of entry into the bladder prevents urine from flowing backward into the ureter. The urinary bladder is able to expand and contract according to how much urine it contains. As it fills with urine, the walls of the bladder stretch and become thinner, with the bladder itself lengthening to 12.5 cm (5 in) or more and holding up to about 0.5 liter (1 pt) of urine. A ringlike sphincter muscle surrounds the bladder's outlet and prevents spontaneous emptying. As the bladder becomes full, stretch-sensitive receptors in its walls are stimulated, and the person becomes aware of the fullness. When the person is ready to urinate, or expel urine, the sphincter relaxes and urine flows from the bladder to the outside through the urethra. In females, the urethra is about 3.8 cm (1.5 in) long and is strictly a urinary passage. In males, the urethra is about 20 cm (8 in) long; it passes through the penis and also serves to convey semen during sexual intercourse. In addition to their vital role in ridding the body of wastes through the production of urine, kidneys play important regulatory roles. They maintain water balance, ensuring that the amount of water in body tissues remains at a constant level. So, for example, if a person drinks a lot of water one day, but little water the next, the kidneys are able to adapt by regulating the water balance in the tissues. The kidneys also control calcium levels in the blood to maintain healthy bones. They aid in regulating the acid-base balance of the blood and body fluids so that all body processes can proceed smoothly. By controlling salt levels, the kidneys help regulate blood pressure. Finally, they stimulate the body to make red blood cells, the primary component of healthy blood. Properly functioning kidneys are so

vital to health that if they cease to function, death follows within days.

All vertebrates dispose of excess water and other wastes by means of kidneys. The kidneys of fish and amphibians are comparatively simple, while those of mammals are the most complex. Fish and amphibians absorb a great deal of water and, as a result, must excrete large quantities of urine. In contrast, the urinary systems of birds and reptiles are designed to conserve water; these animals produce urine that is solid or semisolid.

Nervous

Organization: Central nervous system – Brain, spinal cord

Motor nervous system – output to voluntary muscles, glands, involuntary muscles

Sensory nervous system – input from receptors

Efferent nerves – carry information out of the CNS

Afferent nerves – carry information into the CNS

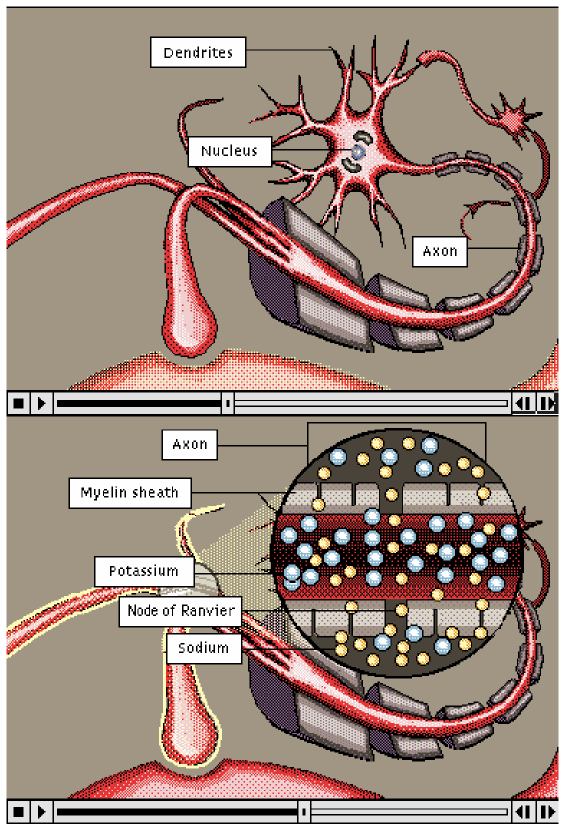
Types of neurons: Receptor → Sensory neuron → association neuron → motor neuron → muscle

Reflex: A gland or muscle is stimulated before the brain has control

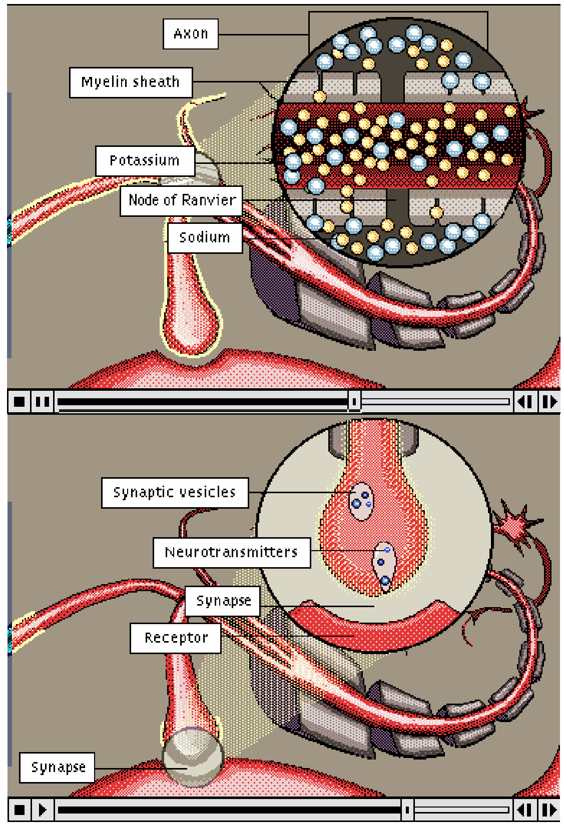
Parasympathetic – at rest

Sympathetic – tense situations

How a nerve impulse is sent



At rest – Chemical balance in the neuron – more potassium inside than outside, more sodium outside



When an impulse arrives, the membrane at the Node of Ranvier is stimulated, causing sodium ions to leak into the axon. The impulse is sent along the axon.

When the impulse reaches a synaptic terminal, neurotransmitters flow out of the neuron into the receptors of another neuron, causing the signal to start again.

This is the end of the study guide. If you find any errors or have any questions or comments about this study guide, feel free to email me at fenguin@gmail.com. Thanks a lot for reading, and good luck on finals!