

Animals and Ecology

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Chapter 39: Form, Function, and Adaptation

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Form, Function, and Adaptation

- Anatomy
- Physiology
- Adaptations
- Trade-off
- Spermatophore
- Acclimatization

Tissues, Organs, and Systems

- Tissue
- Connective tissue
 - Loose connective tissue
 - Dense connective tissue
 - Supporting connective tissue
 - Fluid connective tissue
- Nervous tissue
 - Neurons
 - Dendrites
 - Axon
- Muscle tissue
 - Skeletal muscle
 - Cardiac muscle

- Smooth muscle
- Epithelial tissues
 - Organ
 - Gland
 - Apical
 - Basolateral
 - Basal lamina
- Organ system

How Does Body Size Affect Animal Physiology?

- Surface area vs. volume theory
- Metabolic rate
- Basal metabolic rate (BMR)
- Gills
- Adaptations for increased surface area
 - Flattening
 - Folding
 - Branching

Homeostasis

- Homeostasis
- Regulate
- Conform
- Set point
- Homeostatic system:
 - Sensor
 - Integrator
 - Effector
- Hypothalamus
- Negative feedback

Thermoregulation: A Closer Look

- **Thermoregulate**
- **Thermoregulatory strategies:**
 - **Endotherm**
 - **Ectotherm**
 - **Homeotherms**
 - **Poikilotherms**
 - **Torpor**
 - **Hibernation**
- **Countercurrent exchanger**

Chapter 39: Review

Form, Function, and Adaptation

- Animal structures and their functions represent adaptations, which are heritable traits that improve survival and reproduction in a certain environment.
- Adaptations involve trade-offs, or inescapable compromises between traits.
- Acclimatization is a reversible response to the environment that improves physiological function in that environment.

Tissues, Organs, and Systems

- Animal cells with a common function are grouped together into four general types of tissue: connective tissue, nervous tissue, muscle tissue, and epithelial tissue.
- Organs are structures that are composed of two or more tissues that together perform specific tasks.
- Organ systems comprise organs that work together in an integrated fashion to perform one or more functions.

How Does Body Size Affect Animal Physiology?

- Large animals have smaller surface area/volume ratios than small animals. As animals grow, their volume increases more rapidly than their surface area.
- Large animals have low mass-specific metabolic rates, in keeping with their relatively small surface area for exchanging the oxygen and nutrients required to support metabolism and the wastes and heat produced by metabolism.
- The relatively high surface area of small animals means that they lose heat extremely rapidly.

Homeostasis

- Homeostasis refers to relatively constant physical and chemical conditions inside the body.
- Homeostasis in a fluctuating environment is usually achieved by regulation.
- Animals have set points, or target values, for various body parameters. When a parameter is not at its set point, negative feedback occurs. Responses to negative feedback return the parameter to the set point and result in homeostasis.
- Most animals have a set point for body temperature. If an individual overheats, it may pant, sweat, or seek a cool environment; if an individual is cold, it may shiver, bask in sunlight, or fluff its fur or feathers.

Thermoregulation: A Closer Look

- Animals vary from endothermic to ectothermic and from homeothermic to poikilothermic.
- Endotherms can be active in cold environments but must obtain a lot of energy to fuel their metabolism. Ectotherms do not require as much energy, but their activity depends on environmental temperature.
- Countercurrent heat exchangers have vessels in close contact that carry warm and cool fluids in opposite directions.

Chapter 40: Water and Electrolyte

1. Osmoregulation and Excretion
 2. Water and Electrolyte in Marine Fishes
 3. Water and Electrolyte in Freshwater Fishes
 5. Water and Electrolyte in Vertebrates
- Review

Osmoregulation and Excretion

- Electrolyte
- Diffusion
- Osmosis
- Osmolarity
- Osmoregulation
- Osmoconformers
- Isosmotic
- Osmoregulators
- Hyperosmotic
- Hyposmotic
- Aquaporins
- Ammonia
- Urea
- Uric acid

Water and Electrolyte in Marine Fish

- Rectal gland
- Ouabain
- Interstitial fluid

Water and Electrolyte in Freshwater Fish

- Osmoregulatory cells may be in different locations
- Different forms of Na^+/K^+ -ATPase may be activated
- The orientation of key transport proteins “flips.”

Water and Electrolyte in Vertebrates

- Kidney
- Ureter
- Bladder
- Urethra
- Nephron
- Cortex
- Medulla
- The Mammalian Kidney:
- Filtration
- Proximal tubule
- Microvilli
- Ion and Water Movement:
- Loop of Henle
- A Comprehensive View of the Loop of Henle:
- Vasa recta
- Distal tubule
- Collecting duct
- Hormones Involved:
- Cloaca

Chapter 40: Review

Osmoregulation and Excretion

- Solutes move across membranes via passive transport, facilitated diffusion, or active transport. Water moves across membranes by osmosis.
- In most animals, epithelial cells that selectively transport water and electrolytes are responsible for homeostasis.
- The mechanisms involved in regulating water and electrolyte balance vary widely among animal groups because different habitats present different types of osmotic stress.
- The type of nitrogenous waste excreted by an animal is affected by its phylogeny and its habitat type. Most fishes excrete ammonia; mammals and most adult amphibians excrete urea; and insects and reptiles excrete uric acid.

Water and Electrolyte in Marine Fishes

- Seawater is strongly hyperosmotic to the tissues of marine bony fishes, so they tend to lose water by osmosis and gain electrolytes by diffusion.
- Marine bony fishes are osmoregulators, whereas cartilaginous fishes including sharks are osmoconformers.
- Epithelial cells in the shark rectal gland and in the gills of marine bony fishes excrete excess salt using Na^+/K^+ ATPase and $\text{Na}^+/\text{Cl}^-/\text{K}^+$ cotransporters located in the basolateral membrane.
- Similar salt-excreting cells also exist in the salt glands of marine birds and other reptiles and in the kidneys of mammals.

Water and Electrolyte in Freshwater Fishes

- Freshwater is strongly hyposmotic to the blood of freshwater fishes, so they tend to gain water by osmosis and lose electrolytes by diffusion.
- Epithelial cells in the gills of freshwater fishes import ions using Na^+/K^+ ATPase located in the basolateral membrane and $\text{Na}^+/\text{Cl}^-/\text{K}^+$ cotransporters located in the apical membrane.

Water and Electrolyte in Vertebrates

- Nephrons in the vertebrate kidney form a filtrate in the renal corpuscle and then reabsorb valuable nutrients, electrolytes, and water in the proximal tubule.
- A solution containing urea and electrolytes flows through the loop of Henle of mammalian kidneys, where changes in the permeability of epithelial cells to water and salt—along with active transport of salt—create a steep osmotic gradient.
- Antidiuretic hormone increases the water permeability of the collecting duct, causing water to be reabsorbed along the osmotic gradient and hyperosmotic urine to be produced.
- The nephrons of fishes, amphibians, and nonavian reptiles do not have loops of Henle and therefore cannot produce urine that is hyperosmotic to the body fluids. However, some of these vertebrates can produce hyperosmotic urine by reabsorbing water from the cloaca or bladder.

Chapter 41: Nutrition

1. Nutritional Requirements
3. How are Nutrients Digested and Absorbed?
4. Nutritional Homeostasis
 - i. Review

Nutritional Requirements

- Ingestion
- Digestive tract
- Digestion
- Absorption
- Essential nutrient
- Essential amino acids
- Essential fatty acids
- Vitamins
- Minerals

How are Nutrients Digested and Absorbed?

- Incomplete digestive tracts
- Complete digestive tracts
- Feces
- Salivary amylase
- Lingual lipase
- Salivary glands
- Esophagus
- Peristalsis
- Crop
- Stomach
- Sphincters

- Pepsin
- Parietal cells
- Mucous cell
- Carbonic anhydrase
- Ulcer
- Ruminants
- Symbiosis
- Cellulase
- Small intestine
- Villi
- Microvilli
- Lacteal
- Proteases
- Pancreas
- Trypsin
- Secretin
- Cholecystokinin
- Gastrin
- Pancreatic amylase
- Pancreatic lipase
- Emulsification
- Liver
- Bile
- Gallbladder
- Large intestine
- Colon
- Rectum
- Cecum

- **Appendix**
- **Coprophagy**
- **Cloaca**

Nutritional Homeostasis

- **Diabetes mellitus**
- **Insulin**
- **Glucagon**
- **Gluconeogenesis**
- **Diabetes mellitus**
 - (1)
 - (2)
- **Body mass index (BMI)**

Chapter 41: Review

Nutritional Requirements

- The diets of animals include fats, carbohydrates, and proteins that provide energy; vitamins that serve as coenzymes and perform other functions; minerals that are used as components of enzyme cofactors or structural materials; and ions of electrolytes required for osmotic balance and normal membrane function.
- Fats contain more energy (about 9 kcal/g) than carbohydrates or proteins (about 4 kcal/g), making fats an efficient way to store energy in the body.

How Are Nutrients Digested and Absorbed?

- Most animals have a digestive tract that begins at the mouth and ends at the anus.
- In many animals, chemical digestion of food begins in the mouth. In mammals, salivary amylase hydrolyzes bonds in starch and glycogen, and lingual lipase hydrolyzes bonds in fats.
- Once food is swallowed, it is propelled down the esophagus by peristalsis.
- Digestion continues in the stomach. In the human stomach, a highly acidic environment denatures proteins, and the enzyme pepsin begins the cleavage of peptide bonds that link amino acids.
- Food passes from the stomach into the small intestine, where it is mixed with secretions from the pancreas and liver.

- In the small intestine, carbohydrate digestion is continued by pancreatic amylase; fats are emulsified by bile salts and digested by pancreatic lipase; and protein digestion is completed by a suite of pancreatic proteases.
- Cells that line the small intestine absorb the nutrients released by digestion. In many cases, uptake is driven by an electrochemical gradient established by Na^+/K^+ -ATPase that favors the diffusion of Na^+ into the cells.
- As solutes leave the lumen of the small intestine and enter cells, water follows by osmosis.
- Water reabsorption is completed in the large intestine, where feces form.
- The structure of organs in the digestive tract varies widely among species, in ways that support processing of the food each species ingests.

Nutritional Homeostasis

- Diabetes mellitus is a condition in which the level of glucose in the blood is abnormally high.
- Type 1 diabetes mellitus is caused by a defect in the production of insulin—a hormone secreted by the pancreas that promotes the uptake of glucose from the blood.
- Type 2 diabetes mellitus is characterized by a failure of cells to respond to insulin.
- The development of type 2 diabetes is correlated with obesity. The incidence of this disease has reached epidemic proportions in many populations.

Chapter 42: Gas Exchange

1. The Respiratory and Circulatory System
2. Air and Water as Respiratory Media
3. Organs of Gas Exchange
4. How are Oxygen and Carbon Dioxide Transported in Blood?
5. Circulation
 - Review

The Respiratory and Circulatory System

- Ventilation
- Diffusion at the respiratory surface
- Circulation
- Diffusion at the tissues
- Cellular respiration
- Respiratory system
- Circulatory system

Air and Water as Respiratory Media

- Partial pressure
- Solubility of the gas in water
- Temperature of the water
- Presence of other solutes
- Partial pressure of the gas in contact with the water

Organs of Gas Exchange

- Gills
- Operculum
- Gill filament
- Gill lamellae

- Countercurrent system
- Tracheae (insect)
- Spiracles
- Trachea (human)
- Bronchi
- Bronchioles
- Lungs
- Alveoli
- Positive pressure ventilation
- Negative pressure ventilation
- Diaphragm
- Dead space

How are Oxygen and Carbon Dioxide Transported in Blood?

- Plasma
- Platelets
- White blood cells
- Red blood cells
- Hemoglobin
- Heme
- Oxygen– hemoglobin equilibrium curve
- Cooperative binding
- Bohr shift
- Carbonic anhydrase

Circulation

- Open circulatory system
- Heart
- Closed circulatory system

- Arteries
- Capillaries
- Veins
- Aorta
- Valves
- Lymphatic system
- Lymph
- Atrium
- Ventricle
- Pulmonary artery
- Pulmonary veins
- Pulmonary circuit
- Systemic circuit
- Venae cavae
- Heart murmur
- Pacemaker cells
- Sinoatrial (SA) node
- Intercalated discs
- Electrocardiogram
- Atrioventricular (AV) node
- Systole
- Diastole
- Cardiac cycle
- Systolic blood pressure
- Diastolic blood pressure
- Hypertension
- Baroreceptors
- Cardiovascular disease
- Arteriosclerosis
- Myocardial infarction

Chapter 42: Review

The Respiratory and Circulatory System

- Animal gas exchange involves ventilation, exchange of gases between the environment and the blood, and exchange of gases between blood and tissues.
- Animal circulation involves transportation of gases, nutrients, wastes, and other substances throughout the body.

Air and Water as Respiratory Media

- As media for exchanging oxygen and carbon dioxide, air and water are dramatically different.
- Compared with water, air contains much more oxygen and is much less dense and viscous. As a result, terrestrial animals have to process a much smaller volume of air to extract the same amount of O₂, and the amount of work required to do so is less than in aquatic animals.
- Both terrestrial and aquatic animals pay a price for exchanging gases: Land-dwellers lose water to evaporation; freshwater animals lose ions and gain excess water; marine animals gain ions and lose water.

Organs of Gas Exchange

- The structure of gills, tracheae, lungs, and other gas exchange organs minimizes the cost of ventilation while maximizing the diffusion rates of O₂ and CO₂.
- Consistent with predictions made by Fick's law of diffusion, respiratory epithelia tend to be extremely thin and to be folded to increase surface area.
- In fish gills, countercurrent exchange ensures that the differences in O₂ and CO₂ partial pressures between water and blood are favorable for gas exchange over the entire length of the ventilatory surface.
- Insect tracheae carry air directly to and from tissues.
- In bird lungs, structural adaptations lead to a high ratio of useful ventilatory space to dead space.
- Breathing rate is regulated to keep the carbon dioxide content of the blood stable during rest and exercise.

How are Oxygen and Carbon Dioxide Transported in Blood?

- The tendency of hemoglobin to give up oxygen varies as a function of the PO₂ in surrounding tissue in a sigmoidal fashion. As a result, a relatively small change in tissue PO₂ causes a large change in the amount of oxygen released from hemoglobin.
- Oxygen binds less tightly to hemoglobin when pH is low. Because CO₂ reacts with water to form carbonic acid, the existence of high CO₂ partial pressures in exercising muscle tissues lowers their pH and makes oxygen less likely to stay bound to hemoglobin and more likely to be unloaded into tissues.

- The CO₂ that diffuses into red blood cells from tissues is rapidly converted to carbonic acid by the enzyme carbonic anhydrase. The protons that are released as carbonic acid dissociates bind to deoxygenated hemoglobin. In this way, hemoglobin acts as a buffer that takes protons out of solution and prevents large fluctuations in blood pH.

Circulation

- In many animals, blood or hemolymph moves through the body via a circulatory system consisting of a pump (heart) and vessels.
- In open circulatory systems, overall pressure is low and tissues are bathed directly in hemolymph.
- In closed circulatory systems, blood is contained in vessels that form a continuous circuit. Containment of blood allows higher pressures and flow rates, as well as the ability to direct blood flow accurately to tissues that need it the most.
- In organisms with a closed circulatory system, a lymphatic system collects excess fluid that leaks from the capillaries and returns it to the circulation.
- In amphibians and some reptiles, blood from the pulmonary and systemic circuits may be mixed in the single ventricle.
- In mammals and birds, a four-chambered heart pumps blood into two circuits, which separately serve the lungs and the rest of the body. Crocodilians have a similar heart with a bypass vessel that can shunt blood from the pulmonary to the systemic circuit.
- In vertebrates, the cardiac cycle is controlled by electrical signals that originate in the heart itself.
- Heart rate, cardiac output, and constriction of both arterioles and veins are regulated by chemical signals and by electrical signals from the brain.
- Cardiovascular disease is the leading cause of death in humans.

Chapter 43: Nervous System

1. Principles of Electric Signaling
 2. Dissecting Action Potential
 3. The Synapse
 4. The Vertebrate Nervous System
- Review

Principles of Electric Signaling

- Nerve net
- Central nervous system (CNS)
- Sensory neurons
- Interneurons
- Motor neurons
- Nerves
- Peripheral nervous system
- Reflex
- Cell body
- Dendrites
- Axons
- Electrical potential
- Membrane Potential
- Resting potential
- Ion channel
- Leak channels
- Equilibrium potential
- Action potential
- Three-Phase Signal
 - Depolarization

- Repolarization
- Hyperpolarization
- Excitable membranes

Dissecting Action Potential

- Voltage-gated channels
- Voltage clamping
- Patch clamping
- Neurotoxins
- Action potential propagation
- Refractory state
- Oligodendrocytes
- Schwann cells
- Glia
- Schwann cells
- Glia
- Myelin sheath
- Node of Ranvier
- Multiple sclerosis (MS)

The Synapse

- Synapses
- Neurotransmitters
- Synaptic cleft
- Synaptic vesicles
- Presynaptic neuron
- Postsynaptic cell
- Ligand-gated channels
- Second messengers

- Excitatory postsynaptic potentials (EPSPs)
- Inhibitory postsynaptic potentials (IPSPs)
- Summation
- Axon hillock

The Vertebrate Nervous System

- Afferent division
- Efferent division
- Somatic nervous system
- Autonomic nervous system
- Parasympathetic nervous system
- Sympathetic nervous system
- Enteric nervous system
- General Anatomy of the Human Brain
 - Cerebrum
 - Cerebellum
 - Diencephalon
 - Brain stem
 - Frontal lobe
 - Parietal lobe
 - Occipital lobe
 - Temporal lobe
 - Corpus callosum
 - Hippocampus
- Optogenetics
- Synaptic plasticity
- Neurogenesis

Chapter 43: Review**Principles of Electric Signaling**

- Most neurons have a cell body, multiple short dendrites that receive signals from other cells, and a single axon that transmits electrical signals to other neurons or to effector cells in glands or muscles.
- Studies of the squid giant axon established that neurons have a resting potential maintained by the sodium–potassium pump and potassium leak channels. When $\text{Na}^+/\text{K}^+-\text{ATPase}$ hydrolyzes ATP, it transports 3 Na^+ out of the cell and 2 K^+ in.

Dissecting Action Potential

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The Synapse

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The Vertebrate Nervous System

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