Animals and Ecology

39. Animal Form and Function

- Form, Function, and Adaptation
- Tissues, Organs, and Systems
- How Does Body Size Affect Animal Physiology?
- Homeostasis
- Thermoregulation: A Closer Look
- Review

40. Water and Electrolye Balance

- Osmoregulation and Exertion
- Water and Electrolyte in Marine Fishes
- Water and Electrolyte in Freshwater Fishes
- Water and Electrolyte in Vertebrates
- Review

41. Nutrition

- Nutritional Requirements
- How Are Nutrients Digested and Absorbed?
- Nutritional Homeostasis
- Review

42. Gas Exchange

- The Resipitory and Circulatory System
- Air and Water as Resipitory Media
- Organs of Gas Exchange
- How are Oxygen and Carbon Dioxide Transported in Blood?
- Circulation
- Review

43. Nervous System

- Principles of Electric Signaling
- Dissecting Action Potential
- The Synapse
- The Vertebrate Nervous System
- Review

44. Sensory Systems

–

45. Animal Movement

–

46. Chemical Signals

–

Chapter 39: Form, Function, and Adaptation

Form, Function, and Adaptation

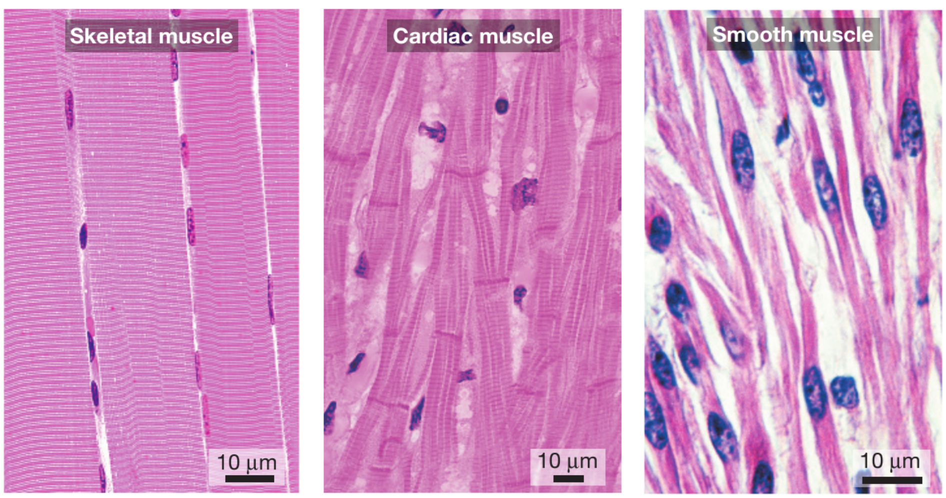
- **Anatomy**: reference to an organism's physical structure, or form.
- **Physiology**: how the physical structures in an organism function.
- **Adaptations**: heritable traits that make individuals more likely to survive and reproduce in a certain environment than individuals that lack those traits.
- **Trade-off**: inescapable compromises between traits
- **Spermatophore**:a packet of sperm surrounded by a large, gelatinous mass. (example for trade offs in crickets)
- **Acclimatization**: Short-term, phenotypic change in an individual in response to environmental fluctuations

Tissues, Organs, and Systems

- **Tissue**: a group of cells that function as a unit.
- **Connective tissue**: cells that are loosely arranged in a liquid, jellylike, or solid matrix.
  - **Loose connective tissue**: an array of fibrous proteins in a soft matrix; it serves as a packing material holding organs and tissues together and as padding under the skin.
  - **Fibroblasts**: cells that make the fibers and extracellular matrix in loose connective tissue.
  - **Dense connective tissue**: found in the tendons and ligaments that connect muscles, bones, and organs. Tendons and ligaments are dominated by tough collagen fibers, also secreted by fibroblasts.
  - **Supporting connective tissue**: a firm extracellular matrix, such as bone and cartilage.
  - **Fluid connective tissue**: cells surrounded by a liquid extracellular matrix such as plasma that surrounds blood.
- **Nervous tissue**: nerve cells, which are also called neurons, and several types of supporting cells.

- **Dendrites**: highly branched, relatively short processes that transmission of signals from adjacent cells to the neuronal cell body.
- **Axon**: a relatively long structure that carries electrical signals from the cell body to other cells.

- **Muscle tissue**: a key innovation in the evolution of animals—like nervous tissue, it appears in no other lineage on the tree of life.
  - **Skeletal muscle**: attaches to bones and exerts a force on them when it contracts and has long cells with a striated, or striped, appearance produced by an overlapping arrangement of proteins.
  - **Cardiac muscle**: makes up the walls of the heart and is responsible for pumping blood throughout the body. The branching pattern of cardiac muscle allows electrical signals to spread throughout all cells of the heart, resulting in their coordinated contraction and relaxation.
  - **Smooth muscle**: cells, which are tapered at each end, form a muscle tissue that lines the walls of the digestive tract and the blood vessels.

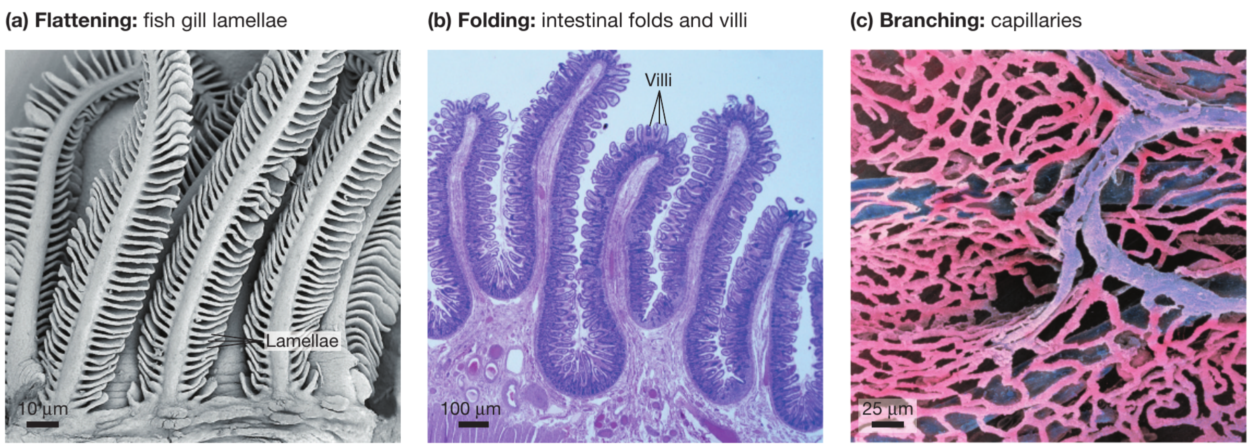


Long cells, voluntary movement | **Branched cells,** involuntary movement | **Tapered cells,** involuntary movement

- **Epithelial tissues**: tissue that covers the outside of the body, line the inner surface of many organs, and form glands.
  - **Organ**: a structure that serves a specialized function and consists of two or more tissues
  - **Gland**: an organ that secretes specific molecules or solutions such as hormones or digestive enzymes.
  - **Apical**: faces away from other tissues and toward the environment
  - **Basolateral**: faces the interior of the animal and connects to connective tissues.
  - **Basal lamina**: the connection made by a layer of fibers on the basolateral side.
- **Organ system** : m consists of groups of tissues and organs that work together to perform one or more functions.

How Does Body Size Affect Animal Physiology?

- **Metabolic rate**: the overall rate of energy consumption by an individual.
- **Basal metabolic rate (BMR)**: the rate at which an animal consumes oxygen while at rest, with an empty stomach, under normal temperature and moisture conditions.
- **Gills**: organs that allow the exchange of gases and dissolved substances between the animals' blood and the surrounding water.
- **Adaptations for increased surface area**:
  - **Flattening**: Fish have gill lamellae—thin sheets of epithelial cells that provide the gill with an extremely high surface area relative to its volume.
  - **Folding**: portions of the digestive tract where nutrients are transported into the body, the surface of the structure is folded. Extending from these folds are narrow projections called villi.
  - **Branching**: a highly branched network of small, thin-walled blood vessels called capillaries, which are the sites where gases, nutrients, and waste products diffuse into and out of blood, and branching greatly increases their surface area.



Homeostasis

- **Homeostasis**: stability in the chemical and physical conditions within an organism's cells, tissues, and organs.
- **Regulate**: to actively maintain relatively constant internal conditions even when the environment fluctuates.
- Epithelia are responsible for forming an internal environment that can be dramatically different from the external environment and for allowing physical and chemical conditions inside an animal to be maintained at relatively constant levels.
- **Homeostatic system:**:A homeostatic system consists of three general components: a sensor, an integrator, and an effector.
- **Hypothalamus**:a receptor region in the brain that responds to changes in blood temperature.

Thermoregulation: A Closer Look

- **Thermoregulatory strategies:**:conduction, convection, radiation, and evaporation.
  - **Endotherm**: produces heat.
  - **Ectotherm**: relies on heat.
  - **Homeotherms**: keep their body temperature constant
  - **Poikilotherms**: allow their body temperature to rise or fall depending on environmental conditions.
  - **Torpor**: reduction of metabolic rate and that allows body temperature to drop, a form of poikilothermy.
  - **Hibernation**: Extended periods of Torpor.
- **Countercurrent exchanger**: fluids that flow through adjacent pipes in opposite directions to reduce heat loss.

Chpater 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

Osmoregulation and Exertion

- **Electrolyte**: compound that dissociates into ions when dissolved in water. Electrolytes got their name because they conduct electrical current.
- **Osmosis**: movement of water down its gradient across a semi permeable membrane
- **Osmoregulation**:is the process by which organisms control the concentration of water and solutes in their bodies.
- **Osmoconformers**: animals with concentrations of electrolytes and other solutes that match those of the sea.
- **Isosmotic**: solute concentrations inside and outside these animals are equal.
- **Osmoregulators**: most marine invertebrates, marine and fresh water bony fishes and terrestrial animals. These organisms actively regulate osmolarity inside their bodies to achieve homeostasis.
- **Hyperosmotic**: the solution outside the body has a higher solute concentration than the solution inside.
- **Hyposmotic**: higher solute concentration than the freshwater outside
- **Aquaporins**: specialized membrane channels where water follows by osmosis due to cells that transport ions and that set up an osmotic gradient.
- **Ammonia**: the result of excess amino acids and nucleic acids when broken down in catabolic reactions and of which animals must secret since it raises the pH of cells.
- **Urea**: a much less toxic compound created by enzyme-catalyzed reactions of ammonia.

SUMMARY Table 40.1 Attributes of Three Forms of Nitrogenous Waste

Attribute	Ammonia	Urea	Uric Acid
Solubility in water	high	medium	very low
Amount of water required for excretion	high	medium	very low
Toxicity	high	medium	low
Groups where it is the primary waste	most bony fishes, aquatic invertebrates	mammals, most adult amphibians, sharks, rays, skates	birds and other reptiles, most terrestrial arthropods (insects, spiders)
Method of synthesis	product of breakdown of amino acids and nucleic acids	synthesized in liver, starting with ammonia or amino groups from amino acids	synthesis starts with nucleic acids
Energy cost of synthesis	low	high	high
Method of excretion	in urine, and diffuses across gills	in urine (mammals); diffuses across gills (sharks)	with feces

Water and Electrolyte in Marine Fish

- **Rectal gland**: an gland in sharks that secretes a concentrated salt solution.
- **Ouabain**: toxic to animals because it binds to Na+/K+ATPase and prevents it from functioning and strong evidence that Na+/K+ATPase is essential for salt excretion.
- **Interstitial fluid**: the extra-cellular fluid surrounding the rectal gland.

Water and Electrolyte in Freshwater Fish

- **Osmoregulatory cells may be in different locations**: when osmotic stress changes, the structure of the gill epithelium changes. Specifically, active pumping of ions takes place in different populations of cells in seawater and freshwater.
- **Different forms of Na^+/K^+-ATPase may be activated**: the form activated when salmon are in seawater differs from the one activated when they are in freshwater.
- **The orientation of key transport proteins "flips."**: When the fish are in seawater, the protein is located in the basolateral membrane of chloride cells. But when they are in freshwater, the protein is located in the apical membrane.

Water and Electrolyte in Vertebrates

- **Kidney**: the key organ of the urinary system osmoregulation primally occurs.
- **Ureter**: a long tube where the urine that forms in the kidney is transported.
- **Bladder**: the storage organ urine in the ureter is transported to.
- **Urethra**: where urine is transported from bladder to the body surface.
- **Nephron**: small structures that are the basic functional unit of the kidney and makes up most of

the kidney's mass. Nephrons work involved in maintaining water and electrolyte balance. f

- **Cortex**: outer region of the an organ.
- **Medulla**: the kidney's inner region.
- **The Mammalian Kidney:**: To move water, cells in the kidney set up a strong osmotic gradient in the interstitial fluid surrounding the nephrons. By regulating these gradients and specific channel proteins, kidney cells exert precise control over loss or retention of water and electrolytes.
- **Renal Corpuscle**: a filtration device where urine formation begins. The renal corpuscle forms a capsule that encloses a cluster of capillaries called a **glomerulus**
- **Bowman's capsule**: region of the nephron that surrounds the glomerulus
- **Proximal tubule**: where filtrate reabsorption begins after leaving the Bowman's capsule.
- **Microvilli**: small hairs that greatly increase the surface area of this epithelial cells of the proximal tubule.
- **Loop of Henle**: the location to which fluid that emerges from the proximal tubule flows to. In about 20 percent of the nephrons present in a human kidney, the loop is long and plunges from the cortex of the kidney deep into the medulla.
- **A Comprehensive View of the Loop of Henle:**:
- **Vasa recta**:
- **Distal tubule**:
- **Collecting duct**:
- **Hormones Involved:**:
- **Cloaca**:

Chaper 40: Review

Osmoregulation and Exertion

- 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 $Na^+/Cl^+/K^+$ cotransporters located in the basolateral membrane.
- Similar saltexcreting 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 $Na^+/Cl^-/K^+$ 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 Resipitory and Circulatory System
2. Air and Water as Resipitory Media
3. Organs of Gas Exchange
4. How are Oxygen and Carbon Dioxide Transported in Blood?
5. Circulation

– Review

The Resipitory and Circulatory System

– **Ventilation**

– **Diffusion at the respiratory surface**

– **Circulation**

– **Diffusion at the tissues**

– **Cellular respiration**

– **Respiratory system**

– **Circulatory system**

Air and Water as Resipitory 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 Resipitory 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 Resipitory 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 CO_2 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 Na+/K+-ATPase hydrolyzes ATP, it transports 3 Na+ out of the cell and 2 K+ in.

Dissecting Action Potential

- 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.
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The Synapse

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The Vertebrate Nervous System

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