Animal Structure and Function

The body structures of an animal include organs that are composed of specialized cells grouped into the four basic tissues: epithelial, connective, muscle, and nerves. Organs function together in organ systems. Structure correlates with function in these hierarchical levels of organization, and the functions of an animal are powered by chemical energy derived from food. Metabolic rate determines the amount of energy needed and is higher for endothermic animals and inversely related to body size. Body proportions and posture are related to size.

All cells must be bathed in an aqueous solution. Compact animal bodies have highly folded exchange surfaces and a circulatory system that distributes materials throughout the body. The internal environment is carefully regulated by the process of HOMEOSTASIS.

1. Have a member of your Learning Community Define the term HOMEOSTASIS........

A comparative physiology study of animals illustrates three general themes: the correlation of structure and function, the capacity of organisms to adapt to their environments, both by short-term physiological adjustments and long-term evolutionary changes, along with bioenergetics, as the basis for understanding animal physiology. As was mentioned in the early lectures of the class, hierarchical levels of organization characterize life. Life emerges at the level of the cell. Multicellular organisms have specialized cells grouped into tissues, which may be combined into organs. Various organs may function together in organ systems.

Tissues are collections of cells with a common structure and function, held together by a sticky extracellular matrix or fibers. Histologists, biologists who study tissues-classify tissues into four categories.

Epithelial tissue lines the outer and inner surfaces of the body in protective sheets of tightly packed cells. Cells at the base of an epithelium are attached to a basement membrane, a dense layer of extracellular matrix. A simple epithelium has one layer, whereas a stratified epithelium has multiple layers of cells. The shape of cells at the free surface may be squamous (flat), cuboidal (boxlike), or columnar (pillar-like). Some epithelia are specialized for absorption or secretion. Mucous membranes lining the gut and the air passages secrete mucus. The small intestine lining also releases digestive enzymes and absorbs nutrients. Cilia on epithelium lining the trachea sweep particles trapped in mucus away from the lungs.

2. Name the 2 types of epithelia illustrated in the figures to the right. One of these forms the outer skin and the other lines the digestive tract. Explain why each would be found at its location?

A. ________________        B. ________________
3. Identify the types of Connective Tissue and their components in the 3 figures to the right.

**Connective tissue** connects and supports other tissues and is characterized by having relatively few cells suspended in an extracellular matrix of fibers, which may be embedded in a liquid, jellylike or solid ground substance.

**Loose connective tissue** attaches epithelia to underlying tissues and holds organs in place. Its loosely woven fibers are of three types: **Collagenous fibers** are made of collagen and have great tensile strength that resists stretching. **Elastic fibers,** made of the protein elastin, can stretch and provide resilience. Branched and thin **reticular fibers** are composed of collagen and form a tightly woven connection with adjacent tissues. The most common types of cells embedded in loose connective tissue are **fibroblasts,** which secrete the protein of the extracellular fibers, and **macrophages,** amoeboid cells that engulf bacteria and cellular debris by phagocytosis.

**Adipose tissue** is a special form of loose connective tissue that pads and insulates the body and stores fuel reserves. Adipose cells each contain a large fat droplet.

**Fibrous connective tissue,** with its dense arrangement of parallel collagenous fibers, is found in **tendons,** which attach muscles to bones, and in **ligaments,** which join bones together at joints.

**Cartilage** is composed of collagenous fibers embedded in a rubbery ground substance called chondroitin sulfate, both secreted by **chondrocytes** found in scattered lacunae in the ground substance. Cartilage is a strong but somewhat flexible support material, making up the skeleton of sharks and vertebrate embryos.

**Bone** is a mineralized connective tissue formed by **osteocytes** that deposit a matrix of collagen and calcium phosphate, which hardens into hydroxyapatite. **Haversian** systems consist of concentric layers of matrix deposited around a central canal containing blood vessels and nerves. Osteocytes are located in lacunae within the matrix and are connected to one another by thin cellular extensions. In long bones, the hard outer region is compact bone, whereas the interior is a spongy bone tissue filled with bone marrow. Red bone marrow, near the ends of long bones, manufactures blood cells.

**Blood** is a connective tissue that has a liquid extracellular matrix called plasma, containing water, salts, and dissolved proteins. Erythrocytes (red blood cells) carry oxygen, leukocytes (white blood cells) function in defense, and cell fragments called platelets are involved in the clotting of blood.

**Muscle tissue** consists of long, contractile cells that are packed with microfilaments of actin and myosin. **Skeletal muscle**-also called **striated muscle** because it looks striped due to the arrangement of overlapping filaments-is responsible for voluntary body movements. **Cardiac muscle,** forming the wall of the heart, is also striated, but its cells are branched, joined at their ends by intercalated discs that relay signals to synchronize the heartbeat. **Smooth muscle** is composed of spindle-shaped cells lacking striations. It is found in the walls of the digestive tract, arteries, and other internal organs. Unlike voluntary skeletal muscle, smooth muscle is often called involuntary because it is not generally under conscious control.

4. Identify the types of vertebrate muscle cells depicted in the pictures to the left.
   What are the dark bands in fig. a, and what is their function?

5. There are 11 organ systems in mammals. How many of them can your Learning Community name?

6. Have one member each, in turn, fill-in the table below, which details the structure and function of the four major types of vertebrate animal tissues.
Bioenergetics is fundamental to all animal functions

Animals exchange energy with the environment by taking in food, from which they harvest ATP for cellular work and chemical energy, and carbon skeletons for biosynthesis, and returning heat to the environment.

**Metabolic Rate** The total energy an animal uses in a unit of time is its **metabolic rate**. Energy is measured in **calories** (cal) or **kilocalories** (kcal). Metabolic rate can be measured by placing an animal in a calorimeter and measuring heat production. The rate of oxygen consumption, also a measure of metabolic rate, can be determined with a respirometer. Metabolic rates are influenced by age, sex, size, activity level, time of day, and other variables. Endothermic animals (birds and mammals) require more energy to sustain minimal life functions than do ectotherms that do not use metabolic heat to maintain a constant body temperature.

The **basal metabolic rate (BMR)** for an endotherm is described as the number of kcal needed per hour when totally at rest, fasting, and nonstressed. The **standard metabolic rate (SMR)** is the metabolic rate of a resting, fasting ectotherm determined at a specific temperature. Metabolic rates during intense physical exercise may be five to ten times the BMR or SMR.

**Body Size and Metabolic Rate** The energy required to maintain each gram of body weight is inversely related to body size. Smaller animals have higher metabolic rates, breathing rates, blood volume, and heart rates. With a greater surface-to-volume ratio, small animals may have a higher energy cost to maintain a stable body temperature. The fact that ectotherms also show this inverse relationship indicates that other factors must contribute to its cause.

7. (a) Which animal, a rabbit or a bear, would have a higher BMR?

(b) which animal would have a higher SMR ?

(c) which animal of the four mentioned in this question, would consume the most cal/gm of body weight?, and

(d) which of the four animal would consume the most total calories?

**Homeostatic Mechanisms and Water Balance**

Animals are able to survive large fluctuations in their external environment by maintaining a relatively constant internal environment. The physiological adjustments that maintain homeostasis, such as osmoregulation, enable organisms to cope

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<thead>
<tr>
<th>Tissue</th>
<th>Structural Characteristics</th>
<th>General Functions</th>
<th>Specific Examples</th>
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with short-term environmental changes. These mechanisms developed by natural selection as populations evolved in specific environments. Homeostatic mechanisms temper changes in the internal body fluid that bathes the cells, either hemolymph in animals with open circulatory systems or interstitial fluid serviced by blood in those with closed circulatory systems.

Cells require a balance between water uptake and loss. Whether an animal lives in salt water, fresh water, or on land, water gain must balance water loss in body cells. Interstitial fluid must be in osmotic balance with the cytosol. Osmosis is the diffusion of water across a selectively permeable membrane that separates two solutions differing in osmolarity (moles of solute per liter). Osmolarity is expressed in units of milliosmoles per liter (10⁻³ moles/L). Isosmotic solutions are equal in osmolarity, and there is no net osmosis between them. There is a net flow of water across a membrane from a hypoosmotic (more diluted) to a hyperosmotic (more concentrated) solution.

**Osmoconformers and Osmoregulators.** **Osmoconformers** are isosmotic with their aqueous surroundings and do not regulate their osmolarity. **Osmoregulators** must get rid of excess water if they live in a hypoosmotic medium or take in water to offset osmotic loss if they inhabit a hyperosmotic environment. Osmoregulation is energetically costly because animals must actively transport solutes in order to maintain osmotic gradients needed to gain or lose water.

Most animals are **stenohaline**, able to tolerate only small changes in external osmolarity. Animals that are **euryhaline** can survive in different osmotic environments by conforming or by maintaining a constant internal osmolarity.

**Maintaining Water Balance in Different Environments.** Most marine invertebrates are osmoconformers, whereas most marine vertebrates are osmoregulators. Sharks have an internal salt concentration lower than that of seawater because their rectal glands pump salt out of the body. They maintain an osmolarity slightly higher than that of seawater, however, by retaining urea (a nitrogenous waste product) and trimethylamine oxide (which protects proteins from the damaging effects of urea) within their bodies. They dispose of excess water in urine produced in kidneys.

Many marine bony fishes, having evolved from freshwater ancestors, are hypoosmotic to seawater and must drink large quantities of seawater to replace the water they lose by osmosis. Excess salts are pumped out through salt glands and other ions are excreted in the scanty urine.

Freshwater animals constantly take in water by osmosis. Protozoa use contractile vacuoles to pump out excess water. Freshwater animals excrete large quantities of dilute urine. Salt Supplies are replaced from their food or, in some fish, by active uptake of ions across the gills.

Some animals are capable of **anhydrobiosis**, or cryptobiosis -surviving dehydration in a dormant state. Anhydrobiotic roundworms produce large quantities of trehalose, a disaccharide that replaces water around membranes and proteins during dehydration. Adaptations to prevent dehydration in terrestrial animals include water-impervious coverings, drinking and eating food with high water content, nervous and hormonal control of thirst, behavioral adaptations such as nocturnal lifestyles, and water-conserving excretory organs.

8. Indicate whether the following are osmoregulators or osmoconformers, and whether they are isosmotic, hyperosmotic, or hypoosmotic to their environment

<table>
<thead>
<tr>
<th>Animal</th>
<th>Osmoregulator or Osmoconformer ?</th>
<th>Osmotic Relation to Environment</th>
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<tr>
<td>marine invertebrates</td>
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<td>terrestrial animal</td>
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**Vertebrate Endocrine Systems and Homeostasis:**

*The Pancreas* Scattered within the exocrine tissue of the pancreas are clusters of endocrine cells known as the islets
of Langerhans. Within each islet are cells that secrete the hormone glucagon and cells that secrete the hormone insulin. These antagonistic hormones regulate glucose concentration in the blood, and negative feedback controls their secretion.

Insulin lowers blood glucose levels by promoting the movement of glucose into body cells from blood, by slowing the breakdown of glycogen in the liver, and by inhibiting the conversion of amino acids and fatty acids to sugar. Glucagon raises glucose concentrations by stimulating the liver to increase glycogen hydrolysis, convert amino acids and fatty acids to glucose, and release glucose to the blood.

In diabetes mellitus, the absence of insulin in the bloodstream or the loss of response to insulin in target tissues reduces glucose uptake by cells. Glucose accumulates in the blood and is excreted in the urine. The body must use fats for fuel, and acidic metabolites from fat breakdown may lower blood pH.

Type I diabetes mellitus, also known as insulin-dependent diabetes, is an autoimmune disorder in which pancreatic cells are destroyed. This type of diabetes is treated by regular injections of genetically engineered human insulin. More than 90% of diabetics have type II diabetes mellitus, or non-insulin-dependent diabetes, characterized either by insulin deficiency or reduced responsiveness of target cells. Exercise and dietary control are often sufficient to manage this disease.

9. Complete the concept map below on the regulation of blood glucose levels.

Neurophysiology......

The 3 main functions of a vertebrate nervous system are sensory input, integration, and motor output. Information from sensory receptors is conducted to integration centers in the brain and spinal cord (CNS - central nervous system). Motor output sends signals to effector cells, muscle, or gland cells. The peripheral nervous system (PNS) carries sensory and motor information between the body and the central nervous system in nerves, bundles of neuron process wrapped in connective tissue. The nervous system is composed of neurons and supporting cells.

A fundamental feature of neurons is the presence of an electrical voltage difference between the cytoplasm and extracellular fluid, the membrane potential. Neurons and muscle cells are electrically excitable cells, i.e., they are able to generate changes in their membrane potentials in response to stimuli. An action potential is a local depolarization of a membrane potential having defined properties and characteristics.

Synapses are functional connections between neurons which conduct an electrical impulses from the synaptic terminal of a presynaptic cells to the membranes of a postsynaptic receptor cell.
10. Have one member, each in turn, identify the label in the following diagrams of neuronal systems.

A.                B.