The study of animal form and function is integrated by the common set of problems that all animals must solve.

- These include
  - how to extract oxygen from the environment,
  - how to nourish themselves,
  - how to excrete waste products, and
  - how to move. (like this)
• **Anatomy** is the study of the *structure* of an organism.

• **Physiology** is the study of the *functions* an organism performs.

• The distinction blurs when we apply the structure’s relation to function theme.
Animals are multicellular organisms with their specialized cells grouped into tissues. In most animals, combinations of various tissues make up functional units called organs, and groups of organs that work together form organ systems.

For example, the human digestive system consists of a stomach, small intestine, large intestine, and several other organs, and each is a composite of different tissues like muscle and nerve.

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• **Tissues** are groups of cells with a common structure and function.

• A tissue may be held together by a sticky extracellular matrix that coats the cells or weaves them together in a fabric of fibers.

• Tissues are classified into four main categories:
  • epithelial tissue,
  • connective tissue,
  • nerve tissue, and
  • muscle tissue.
• Occurring in sheets of tightly packed cells, epithelial tissue covers the outside of the body and lines organs and cavities within the body.

• The cells of epithelium are closely joined and in many epithelia, the cells are riveted together by tight junctions.

• The epithelium functions as a barrier protecting against mechanical injury, invasive microorganisms, and fluid loss.

• The free surface of the epithelium is exposed to air or fluid, and the cells at the base of the barrier are attached to a basement membrane, a dense mat of extracellular matrix.
• Some epithelia, called **glandular epithelia**, absorb or secrete chemical solutions.

  • For example, glandular epithelia lining tubules in the thyroid gland secrete a hormone that regulates fuel consumption.

  • The glandular epithelia that line the lumen of the digestive and respiratory tracts form a **mucous membrane** that secretes a slimy solution called mucus that lubricates the surface and keeps it moist.

    • The free epithelial surfaces of some mucous membranes have beating cilia that move the film of mucus along the surface.

    • In the respiratory tubes, this traps dust and particles.
Connective tissue functions mainly to bind and support other tissues.

- Connective tissues have a sparse population of cells scattered through an extracellular matrix.

- The matrix generally consists of a web of fibers embedded in a uniform foundation that may be liquid, jellylike, or solid.

- In most cases, the connective tissue cells secrete the matrix.
There are three kinds of connective tissue fibers, which are all proteins: collagenous fibers, elastic fibers, and reticular fibers.

**Collagenous fibers** are made of collagen.
- Collagenous fibers are nonelastic and do not tear easily when pulled lengthwise.

**Elastic fibers** are long threads of elastin.
- Elastin fiber provide a rubbery quality.

**Reticular fibers** are very thin and branched.
- Composed of collagen and continuous with collagenous fibers, they form a tightly woven fabric that joins connective tissue to adjacent tissues.
The major types of connective tissues in vertebrates are loose connective tissue, adipose tissue, fibrous connective tissue, cartilage, bone, and blood. Each has a structure correlated with its specialized function.
• **Nervous tissue** senses stimuli and transmits signals from one part of the animal to another.

  • The functional unit of nervous tissue is the **neuron**, or nerve cell.

  • Other nervous tissue cells are called **glial cells**.

![Fig. 40.3](image-url)
• **Muscle tissue** is composed of long cells called muscle fibers that are capable of contracting when stimulated by nerve impulses.

• Arranged in parallel within the cytoplasm of muscle fibers are large numbers of the contractile proteins actin and myosin.

• Muscle is the most abundant tissue in most animals, and muscle contraction accounts for most of the energy-consuming cellular work in active animals.
There are three types of muscle tissue in the vertebrate body: skeletal muscle, cardiac muscle, and smooth muscle.
In all but the simplest animals (sponges and some cnidarians) different tissues are organized into organs.

- Many vertebrate organs are suspended by sheets of connective tissues called mesenteries in body cavities moistened or filled with fluid.
- Mammals have a thoracic cavity housing the lungs and heart that is separated from the lower abdominal cavity by a sheet of muscle called the diaphragm.
1. Physical laws constrain animal form

• Physical requirements constrain what natural selection can “invent,” including the size of single cells.

  • This prevents an amoeba the size of a pro wrestler engulfing your legs when wading into a murky lake.

  • An amoeba the size of a human could never move materials across its membrane fast enough to satisfy such a large blob of cytoplasm.

• In this example, a physical law - the math of surface-to-volume relations - limits the evolution of an organism’s form.
The similar forms of speedy fishes, birds, and marine mammals are a consequence of convergent evolution in the face of the universal laws of hydrodynamics.

Convergence occurs because natural selection shapes similar adaptations when diverse organisms face the same environmental challenge, such as the resistance of water to fast travel.
2. Body size and shape affect interactions with the environment

- An animal’s size and shape have a direct effect on how the animal exchanges energy and materials with its surroundings.
  - As a requirement for maintaining the fluid integrity of the plasma membrane of its cells, an animal’s body must be arranged so that all of its living cells are bathed in an aqueous medium.
  - Exchange with the environment occurs as dissolved substances diffuse and are transported across the plasma membranes between the cells and their aqueous surroundings.
More than a century ago, Claude Bernard made the distinction between external environments surrounding an animal and the internal environment in which the cells of the animal actually live.

The internal environment surrounding the cells of vertebrates is called the interstitial fluid.

This fluid exchanges nutrients and wastes with blood contained in microscopic vessels called capillaries.

How about that dog video if there’s time?
• Today, Bernard’s “constant internal milieu” is incorporated into the concept of homeostasis, and means “steady state,” or internal balance.

• Actually the internal environment of an animal always fluctuates slightly.

• Homeostasis is a dynamic state, an interplay between outside forces that tend to change the internal environment and internal control mechanisms that oppose such changes.

• The term “homeostasis” refers to the processes that make the constant adjustments to maintain a steady state; it is not a synonym for the steady state.
2. Homeostasis depends on feedback circuits

• Any homeostatic control system has three functional components: a receptor, a control center, and an effector.

  • The *receptor* detects a change in some variable in the animal’s internal environment, such as a change in temperature.

  • The *control center* processes the information it receives from the receptor and directs an appropriate response by the *effector*.
• In a negative-feedback system, a change in the variable being monitored triggers the control mechanism to counteract further change in the same direction.

• Owing to a time lag between receptor and response, the variable drifts slightly above and below the set point, but the fluctuations are moderate.

• Negative-feedback mechanisms prevent small changes from becoming too large.

• Most homeostatic mechanisms in animals operate on this principle of negative feedback.
In contrast to negative feedback, positive feedback involves a change in some variable that trigger mechanisms that amplify rather than reverse the change.

For example, during childbirth, the pressure of the baby’s head against sensors near the opening of the uterus stimulates uterine contractions.

These cause greater pressure against the uterine opening, heightening the contractions, which cause still greater pressure.

Positive feedback brings childbirth to completion, a very different sort of process from maintaining a steady state.
3. Metabolic rate per gram is inversely related to body size among similar animals

- One of animal biology’s most intriguing, but largely unanswered questions has to do with the relationship between body size and metabolic rate.
  - Physiologists have shown that the amount of energy it takes to maintain each gram of body weight is inversely related to body size.
  - For example, each gram of a mouse consumes about 20 times more calories than a gram of an elephant.
• The higher metabolic rate of a smaller animal demands a proportionately greater delivery rate of oxygen.

• A smaller animal also has a higher breathing rate, blood volume (relative to size), and heart rate (pulse) and must eat much more food per unit of body mass.