# Human Biology

# HUMAN BIOLOGY

An Exploration of Structure and Function

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# PART I
# DOING WELL IN HUMAN BIOLOGY

In addition to teaching the facts of human biology, a primary goal of this textbook is to support better learning through how the material is presented. This course incorporates some of the foremost scientific research on learning. It attempts to guide you through the material thoughtfully, incorporating data gathered by the Open Learning Initiative from students like you who are learning this subject.

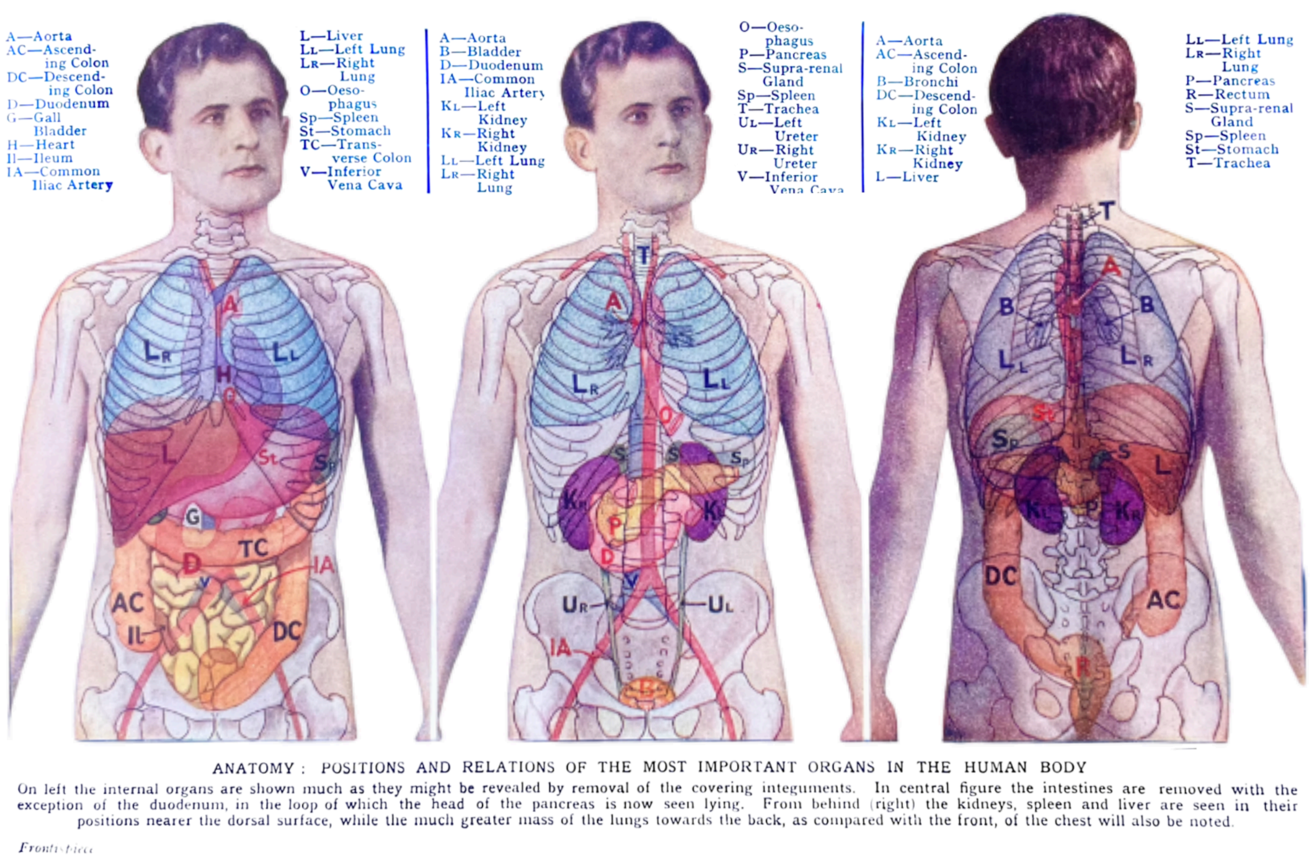


Figure I.1: Positions and Relations of the Most Important Organs in the Human Body. [Credit: Frontspiece, The Modern Home Physician, 1934]

## Media Attributions

- antique anatomy 4 © Victor Robinson (editor), Modern Home Physician, 1934 adapted by C. Seiwert

# PART I

# AN INTRODUCTION TO HUMAN BIOLOGY

## Why Study Human Biology?

You probably have a general understanding of how your body works. Still, to truly understand the intricate functions of the human body and to dispel many misconceptions you have learned about your body over the years, you must approach the study of the body in an organized way.

This course will help you understand those intricacies and attack misconceptions head-on. It will expose you to the complex levels of organization inside the body and provide you with the information you need to delve deeply into the specific aspects of the body systems. This information will prepare you for the more complex topics you will encounter in future courses. There is some agreement among professionals about how to do this and what information must be standard across all Human Biology courses. These agreements are the “Big Picture.”

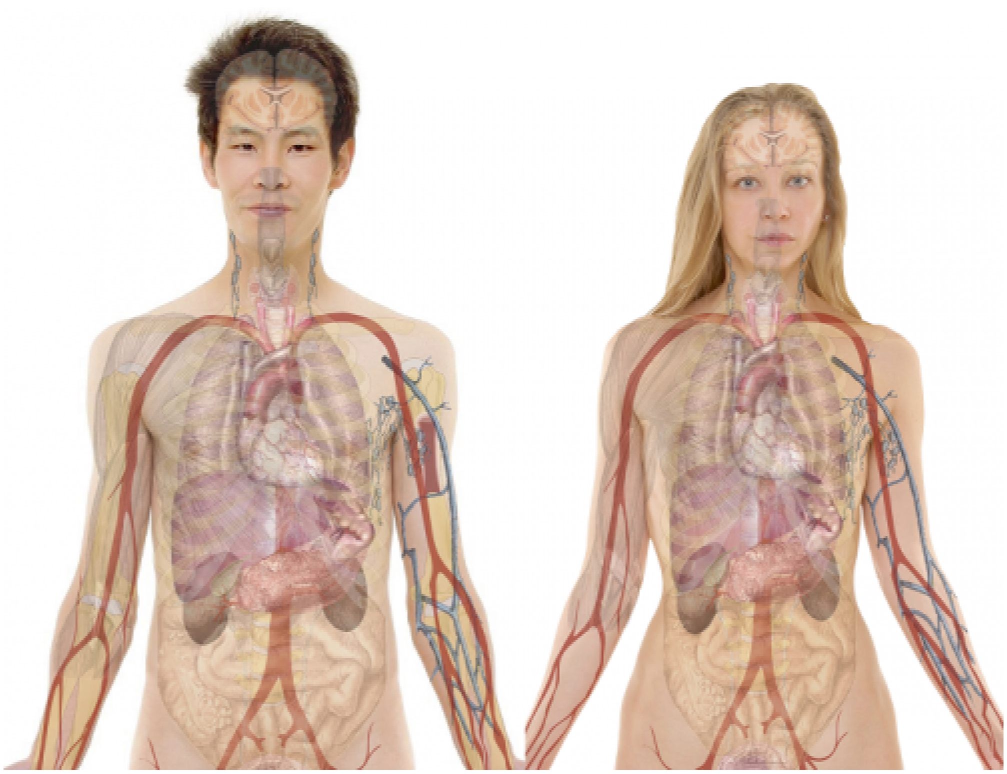

Figure II.1: Diagram of a male and female with their internal organs and blood vessels visible. [Credit: Pixabay, Public Domain]

## What is a Big Picture?

This course aims to teach you how the skills you are learning fit together in a meaningful big picture of Human Biology. The Big Picture will give you an organizational structure to learn the material.

The Big Picture explains why the material is being covered, as well as how the material is related or organized. The Big Picture also illustrates why you might want to invest time in learning this material and what it can do.

## Big Picture Ideas in Human Biology

The Big Picture, Big Ideas, or core principles are all ways to describe the necessary concepts that make up a discipline. For Human Biology and Anatomy and Physiology, various groups have conducted research studies to determine the Big Ideas in this discipline.

They determined that the "Big Ideas in Human Biology" are:

- The processes that occur in living organisms follow the laws of physics and chemistry.
- The cell is the basic unit of life.
- Life requires information to flow within and between cells and between the environment and the organism.
- Living organisms must obtain matter and energy from the external world. Matter and energy are transformed and transferred in different ways to build the organism and perform work.
- Homeostasis (and "stability" in a more general sense) maintains the internal environment in a more or less constant state compatible with life even as the external environment changes.
- Understanding the functioning of the human body requires understanding the relationship between structure and function (at each and every level of organization).
- Living organisms carry out functions at many different levels of organization simultaneously (at the same time).
- All life exists within an ecosystem made up of the physiochemical and biological worlds.
- Evolution provides a scientific explanation for the history of life on Earth and the mechanisms through which changes to life have occurred.

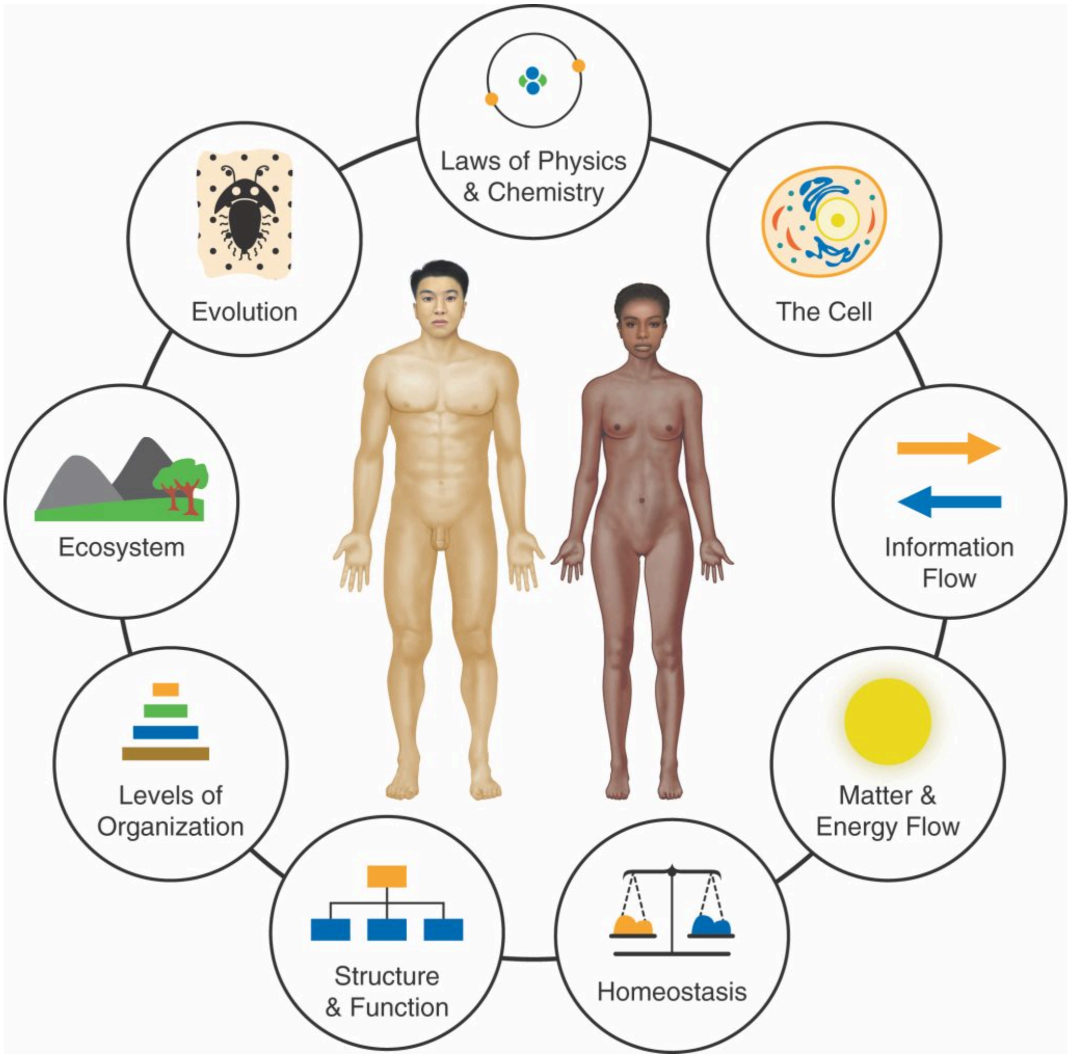


Figure I.2: Big Picture Ideas in Human Biology [Credit: KnowledgeWorks Global Ltd., CC-BY 4.0.]

This text takes these Big Ideas and uses them to structure information about the biology of humans.

We intend for you to begin to think and speak in the language of biology while integrating the knowledge you gain about anatomy (structure) to support explanations of physiology (function). The course focuses on a few themes derived from the Big Ideas, which, when taken together, provide a complete view of what the human body is capable of and the exciting processes going on inside it. These organizational themes are:

1. Structure and function of the body and the connection between the two
2. Homeostasis, the body's natural tendency to maintain a stable internal environment
3. Levels of Organization, the major levels of organization in the human organism from the chemical, biochemical, and cellular levels to the tissues, organs, and organ systems
4. Integration of Body Systems, the mechanisms by which the parts of each system support its common function, and the ways different systems work together.

You can see how these themes directly relate to the Big Ideas. As these themes describe the inner workings of each of the body's organ systems, an integrated collection of organs that function together, those systems can be categorized based on their contribution to the specific vital functions needed for human life. These vital functions provide the context for the whole body and how each organ system plays a role in keeping us alive. We present information about each organ system according to the functions essential to the human body's survival. The vital functions necessary for human life are:

- **Exchange of materials with the environment**
- **Transport of materials within the body**
- **Structure, support, and movement**
- **Protection from the environment**
- **Control and regulation**

All multicellular organisms need these vital functions to operate properly to survive. In addition to understanding the Themes and Vital Functions that help us organize our knowledge about the structure and function of the different body organ systems, knowing and using proper terminology related to body planes and directional terms will also help you in your quest to master Human Biology.

## Body Systems

The introductory chapter will introduce you to all the body systems. In the Introduction to Systems section, you'll see that we have grouped the organ systems according to the Vital Functions they perform. For example, the Digestive and Respiratory Systems are concerned with exchanging substances and information within the environment. In the following major sections of the book, except for Levels of Organization and Homeostasis, you will learn and explore each body system. Your instructor will determine the order in which you learn each system, but each system is described according to the Big Picture themes.

## Body Planes, Words to Describe Regions of the Body, and Directional Terms

Another commonality across body types is the terms used to describe body planes, regions of the body, and directional terms. Health professionals must speak the same language about locating and identifying specific body parts and organs. Body planes, as well as regional and directional terms, are part of this common language. The imaginary vertical and horizontal planes run through the body, cutting it into parts. You will be introduced to this new "language" and given opportunities to practice using it in context. You will become comfortable locating and describing all organs and parts in the body and their relation to each other.

Everything you learn after this section will use this terminology to help you visualize, identify, and locate anatomical structures.

## Media Attributions

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# ORGANIZING CONCEPTS

## Themes in Human Biology

Learning Objectives

Use a thematic framework to make sense of the different parts of human biology.

Everyone has a body and, by adulthood, a general understanding of how it works. But to truly understand the intricate functions of the human body—and the problems that occur when something goes wrong—you must approach the study of the body in an organized way. This course will help you understand the functions of the human body. The text will discuss the details of many complex functional systems but will also look at how all of these systems work in harmony to keep you healthy. As you move through this course, you should keep four main themes in mind: structure and function, homeostasis, levels of organization, and integration of systems.

### 1. Structure and Function

The first theme is the connection between structure and function. You will be studying anatomy, which focuses on the body's structures, and physiology, which focuses on the body's functions. In fact, it is virtually impossible to study one without the other because function relies so completely upon structure.

In biological systems, there is a close link between the structure of a cell or body part and its function. Two factors determine something's structure: its three-dimensional shape and the materials it is made of. The structure that something takes directly influences its possible functions. Consider a piece of wood. Depending on how it is shaped, someone could use it as a spear for hunting, a cup for drinking, a pipe for smoking, or even a flute for playing music. The wood also possesses unique properties that influence how it can be used. For example, a piece of wood could never function as a hot air balloon, no matter its shape. It would always be too heavy to lift off the ground.

At the smallest levels of biological organization, the structure of a molecule determines its function within a cell. In this course, you might investigate the structure of a molecule and then learn what it does. It will help you to remind yourself that this molecule's structure and function are connected.

Enzymes are molecules found within a cell that speed up the rate of the chemical reactions necessary to support life. Enzymes break down food molecules, help build muscle proteins, can destroy toxins, and much more. An enzyme's ability to function depends directly on its three-dimensional shape. If exposed to excessive heat or harsh chemical conditions, enzymes unravel and change shape. When this occurs, the enzymes stop working, and the chemical reactions of life slow down or cease.

At a larger scale, the structure of a cell is directly linked to its function within the body of a **multicellular** organism. The structure also determines function at higher levels of biological organization. Your body's organs function as they do because of how tissues are put together, forming filters, pumps, levers, surfaces for gas exchange, and pipes for air and fluid flow. Consider the following examples. The structure of the bones in the skeletal system provides the support necessary for the function of walking upright. The vocal cords would not be able to fulfill their role—the production of sound—if their structure were disrupted. The large surface area of the small intestine allows it to perform its primary function: absorbing nutrients from food efficiently.

**Learn By Doing 1.1**

- In your own words, describe how structure and function are related.
- Think about your experience of the world. Give an example of the relationship between structure and function from outside biology.

## 2. Homeostasis

The second theme will be homeostasis, the body's natural tendency to maintain a relatively stable internal environment even though conditions around and within us constantly change. Homeostasis drives most of the body's functions. Homeostasis occurs at all different levels. For example, body temperature is regulated around 98.6, a temperature that is optimal for cell function and organism function. To maintain this temperature, we sweat to cool down on a hot day and shiver to increase our temperature when we are cold. Other variables, like blood pressure, blood pH, and blood calcium concentrations, are similarly maintained within a narrow range that is optimal for human health. Many diseases occur because of disruptions in homeostasis.

**Learn By Doing 1.2**

Diabetes Mellitus is a set of metabolic diseases wherein the body either does not produce enough of the hormone insulin or cells do not respond to the insulin produced. This results in high levels of sugar (glucose) in the blood. Diabetes Mellitus results from an inability to control the homeostasis of which of the following properly?

1. insulin levels
2. blood pressure
3. blood glucose levels
4. blood flow

*Hints:*
*Think about the definition of homeostasis.*
*Think about which factor is fluctuating and not being controlled by the body in this disease.*

# 3. Levels of Organization

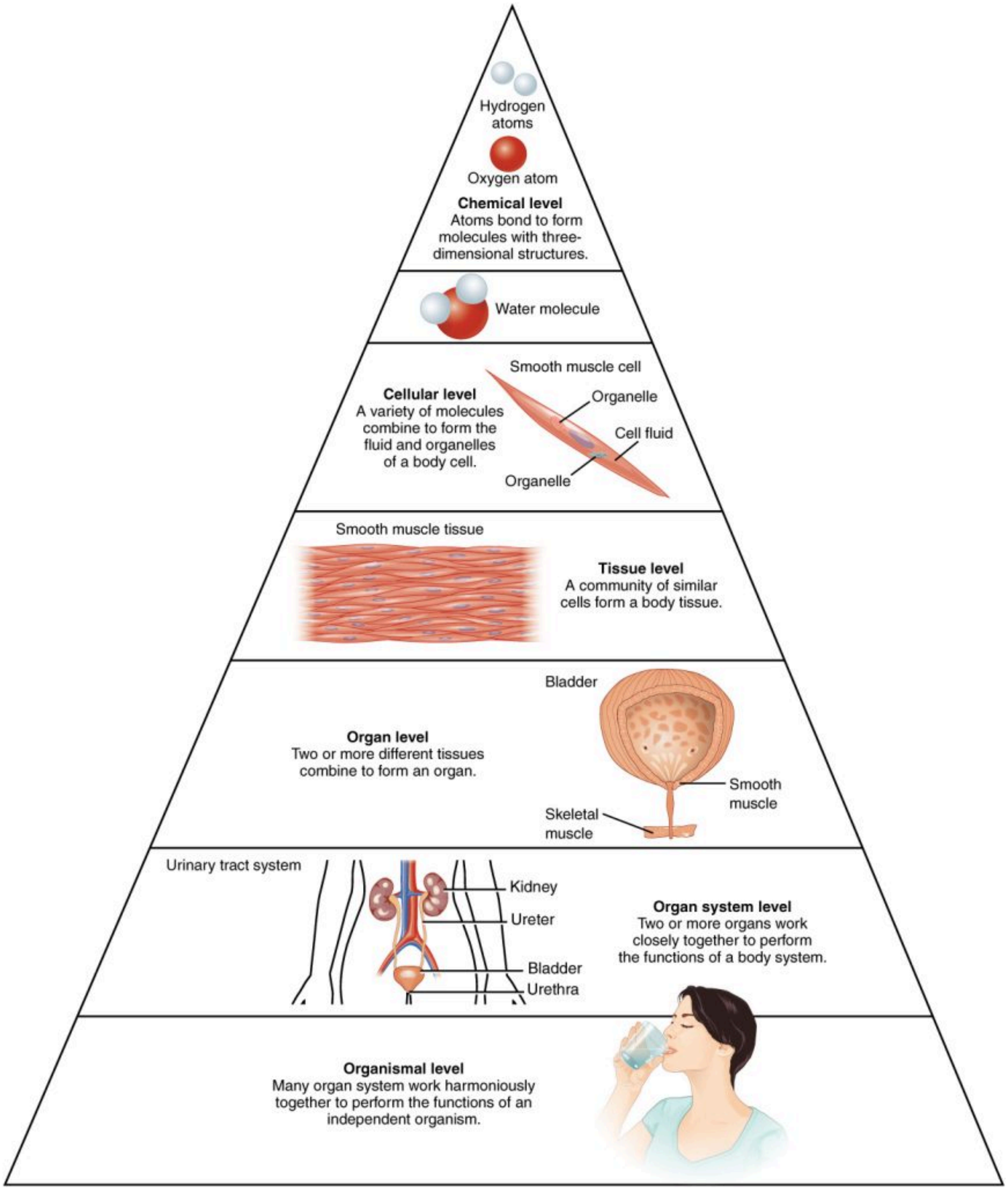


Figure 1.1. The organization of the body often is discussed in terms of six distinct levels of increasing complexity, from the smallest chemical building blocks to a unique human organism. Note: The macromolecule level (which is located between molecules and organelles) isn't shown.

The third theme will be the hierarchical organization of body parts. You can think of the body's components as being organized into a hierarchy of levels. Like all things in the physical world, your body is built from chemical building blocks. The smallest of these building blocks are atoms of elements, which combine to form larger and more complicated structures called molecules. These molecules, such as water, proteins, carbohydrates, nucleic acids, and lipids, are used to build cells. Cells are the smallest unit of organization capable of carrying out all life processes. Groups of related cells that work together to perform specific functions make up tissues, and tissues that work together form organs. Organs do not work independently; they are organized into organ systems that complete more complex tasks. How can you identify hierarchical organization? This type of structure is characterized by the following:

- Each level is made of parts from the level below.
- Complex structures are built out of simpler parts.
- Simple structures can be combined in many different ways.

What are the results of hierarchical organization?

- Each new level of organization has characteristics that were not present in the level below. These are called emergent properties. An **emergent property** is a new feature that arises from combining structures from the level below. For example, Sodium is a silvery, soft, explosive metal. Chlorine is a poisonous green gas. When sodium and chloride combine, table salt is created. Table salt is neither silvery nor green, neither explosive nor poisonous. Table salt is made only of sodium and chloride but has emergent properties (such as making french fries taste delicious) that are not present if the two chemicals are separate.
- Within a level, when the same parts are organized in a different way, differences in function are created. Changing how the elements of a level are organized generates different functions. Consider the digestive system as an example. The function of the digestive system is to bring food into the body and break it down physically and chemically into nutrients that our bodies can use. The digestive system includes the mouth, stomach, intestines, among others. Imagine the result if the order of organs was different!

Understanding this hierarchy is important because disruptions might occur at any level. For example, the depletion of calcium atoms from the body can lead to weak bones. Or a single mutation in a DNA molecule can lead to organ dysfunction, such as the disturbed lung function found in individuals with cystic fibrosis. In fact, disturbed function at higher levels in the hierarchy can be traced to disordered structure at the cellular and molecular levels.

**Learn By Doing 1.3**

Think about your experience of the world. Give an example of the hierarchical organization of a complex structure from outside biology.

# 4. Integration of Systems

Figure 1.2: When playing Jenja, the stability of the tower depends on the interaction of all blocks. Similarly, our organ systems are interdependent. Dysfunction in one system alters homeostasis of the entire body. [Source: Jorge Barrios, 2007; Wikipedia]

Have you ever played a game of Jenga, where you try to remove one block at a time from a tower structure without causing the entire tower to collapse? In this game, each block depends on the other blocks for stability, and if you're not careful, removing a single block can destroy the entire structure. Life is much the same. The various parts of living systems are **interdependent** at levels from the individual to the biosphere. The Merriam-Webster Dictionary defines interdependence as 1: the state of being dependent upon one another and 2: a mutually dependent relationship.

Your trillions of cells are intimately dependent on each other for survival. Your cells are specialized, and you exist because of a massive team effort from all these different cells. If any one of your major organs were to fail suddenly, you might die very quickly. Moreover, your health also depends on trillions upon trillions of bacterial cells that live in and on your body. They provide your cells with vitamins, help keep out invaders, and may even influence your mood. So your body itself is a community of interdependent cells.

Each section of the course will discuss the integration of the body's systems. Every organ system relies on the healthy functioning of other systems to carry out its functions. When these systems all work together, the organism thrives. A breakdown in one system can cause failures in other systems as well.

Learn By Doing 1.4

Describe an example of interdependence among cells within your body.

# Vital Functions for Human Life

Learning Objective

Classify individual body system functions based on their contribution to vital human functions.

This section introduces you to the major organ systems of the body. To put these systems in context, we will first discuss the vital functions of life.

Within any organism, there is a multitude of functions taking place at any given time. Humans, for example, can breathe, talk, digest food, process visual images, and move their bodies simultaneously. While these activities are important, some are essential to the human body's survival. They are vital functions– processes or actions of the body on which life is directly dependent. You will examine five vital functions in this course: control and regulation, structure, support, and movement; exchange with the environment; transport within the body; and protection from the environment.

Learn By Doing 1.5

Think about your own body and its many functions. Which functions are essential? What functions does your body need to perform each day to survive?

*Hint: Think about what your body needs to survive and function properly. All multicellular systems must perform the same vital functions.*

As we said, you will examine five vital functions in this text: control and regulation; structure, support, and movement; exchange with the environment; transport within the body; and protection from the environment. All multicellular systems must perform the same vital functions. Since the human body is a complex organism, we need to bring energy into our bodies, move materials throughout our bodies, move ourselves to new energy sources and regulate all of the complex stuff in our bodies.

So what does this mean? What does this involve? How does the human body do these things? Try answering the questions below to begin broadly thinking about body function within these categories and how they are linked to one or more primary organ systems.

Did I Get This? 1.1

Which of the following concepts would be classified as vital functions of human life?

- fluid transport within the body, and control and regulation
- homeostasis and structure and function
- the nervous system and the cardiovascular system
- the cell is the basic unit of life

## Major Organ Systems of the Body Grouped by Primary Function

Next, we will describe each major category of function and the systems that execute the vital functions. An **organ system** is an integrated collection of organs in the body that work together to perform a vital function. This course will organize the organ systems of the body based on the vital functions defined

**Table 1.1. Major Organ Systems Grouped by Primary Function**

| Function | Organ System |
|---|---|
| Control and Regulation | Nervous and Endocrine Systems |
| Structure, Support, and Movement | Skeletal and Muscular Systems |
| Exchange with the Environment | Digestive and Respiratory Systems |
| Fluid Transport within the Body | Cardiovascular and Lymphatic Systems |
| Protection from the Environment | Integumentary and Lymphatic/Immune Systems |

earlier. Keep in mind, however, that most systems of the body could be placed in more than one category. The major organ systems of the body and their primary functions are shown in Table 1.1.

## Control and Regulation

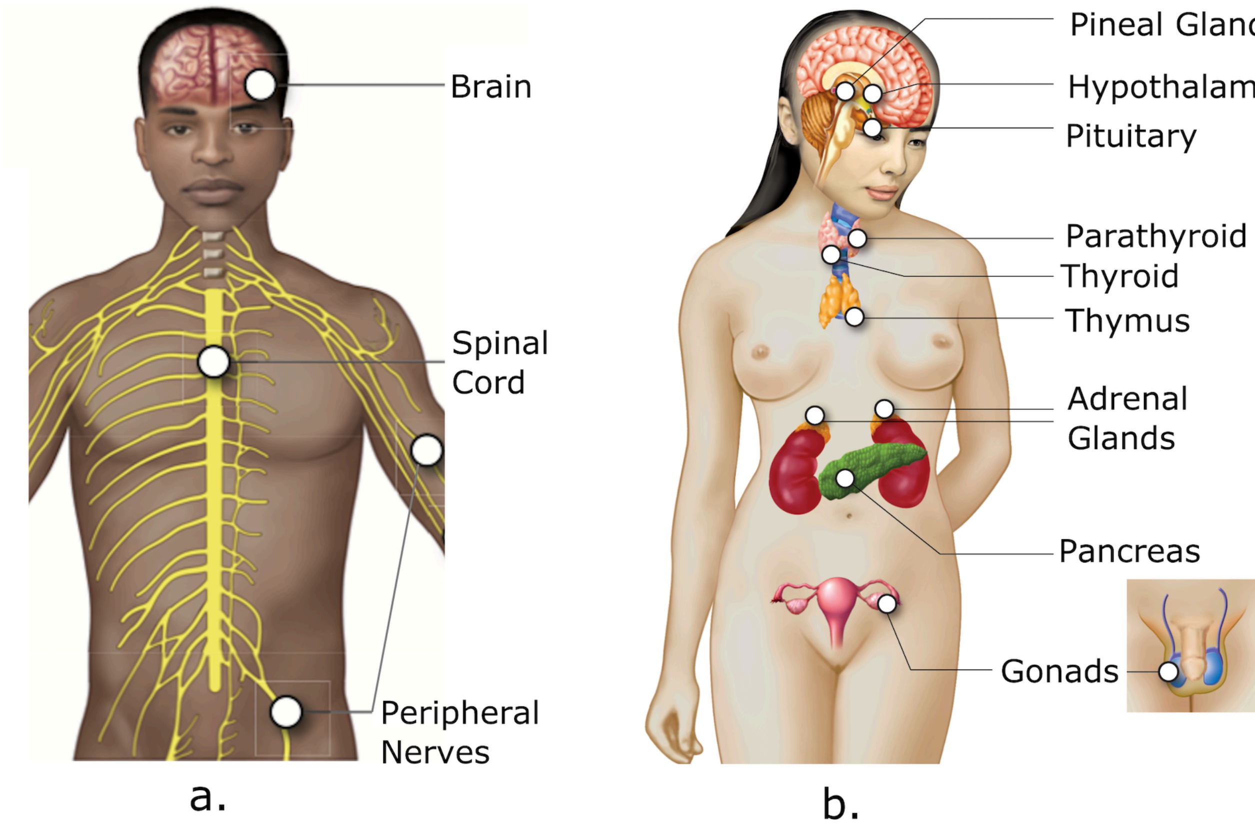


Figure 1.3. Systems Involved in Control and Regulation. a. Nervous System, b. Endocrine System

An organism must constantly gather information and react accordingly to maintain its internal equilibrium. In humans, the nervous system is made up of the brain, nerves, and spinal cord. Sensory organs react to environmental stimuli and signal other systems when actions are needed to bring the body back into balance. The endocrine system, which produces hormones and other regulatory substances, plays a crucial role in maintaining balance among chemical messengers within the body. Locally, most body cells can produce chemical messages that influence the metabolism of other cells. And some organs in other body systems produce chemicals that can travel through the body to regulate metabolic processes in other organs.

## Structure, Support, and Movement

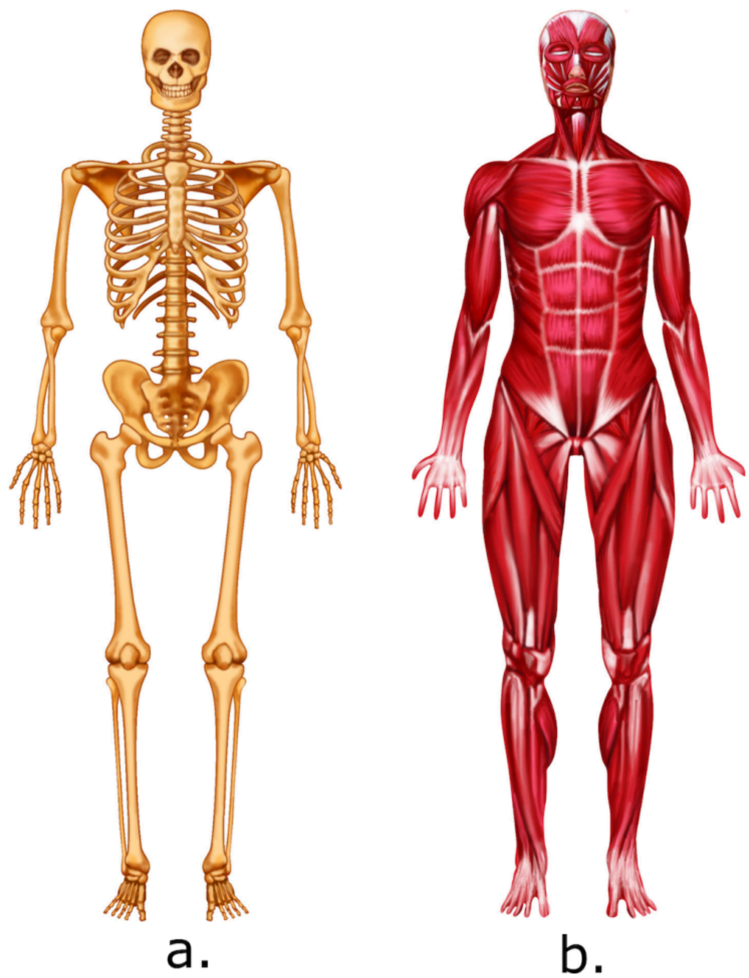


Figure 1.4. Systems Involved in Support, Structure, and Movement. a. Skeletal System, b. Muscular System

The skeletal and muscular systems support the body and allow it to move away from danger, toward food sources, etc. Certain parts of the skeletal system, such as the skull and ribcage, also help to protect the internal organs, such as the brain, heart, and lungs, from damage. The muscular system also allows for movement within the body.

## Exchange with the Environment

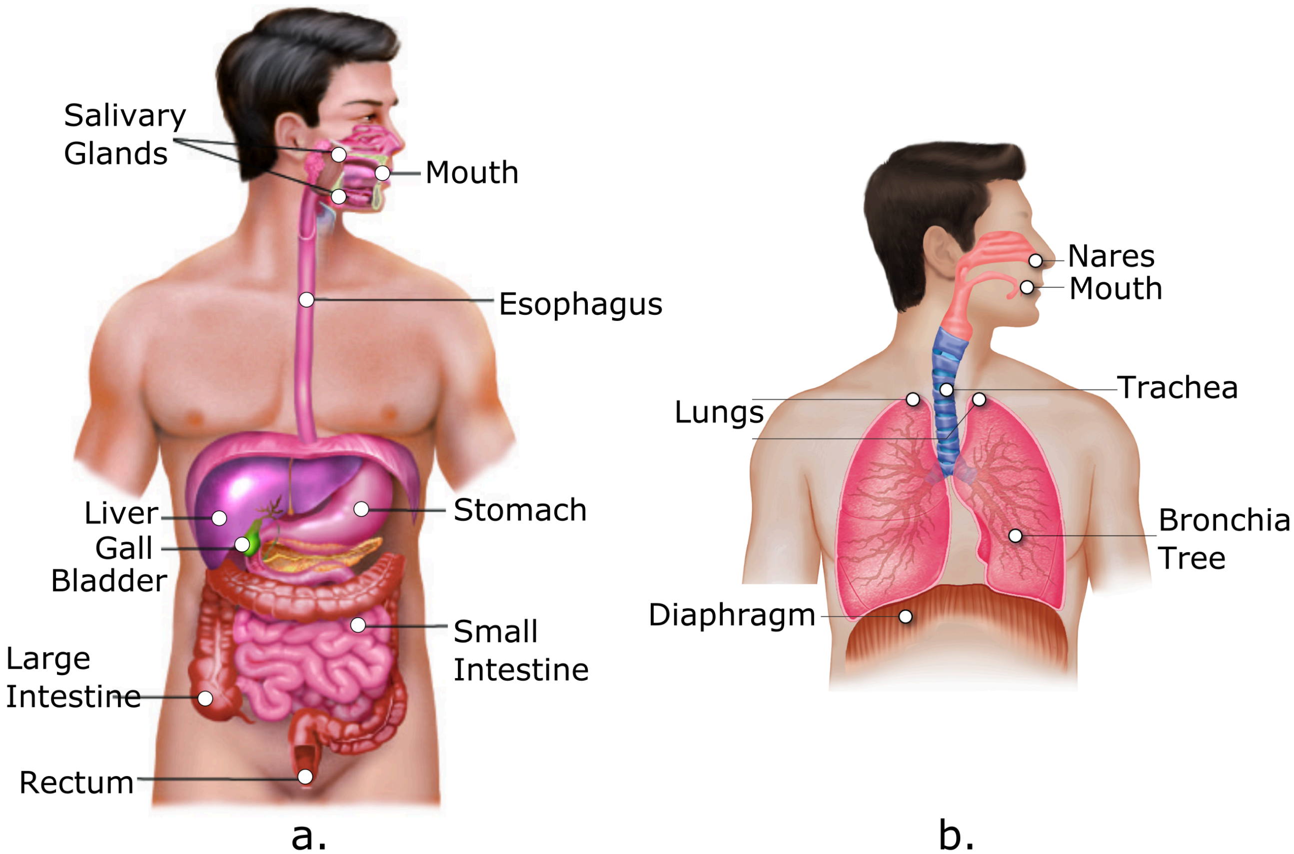


Figure 1.5. Systems Involved with Exchanging Materials with the Environment. a. Digestive System, b. Respiratory System

An organism constantly interacts with its environment. Our bodies must obtain food, water, and oxygen from the world to survive. The human body must also eliminate waste before it reaches toxic levels. Two organ systems are primarily responsible for exchanging material with the environment. The digestive system brings food and water into the body and eliminates solid wastes. The respiratory system brings in oxygen and removes carbon dioxide.

The urinary system doesn't take in anything from the environment but does eliminate waste products of metabolism from the body fluid. However, this is just one of several roles that the urinary system plays in maintaining homeostasis of body fluids, so we will explore it more extensively in the following vital function category involving body fluids.

## Fluid Transport within the Body

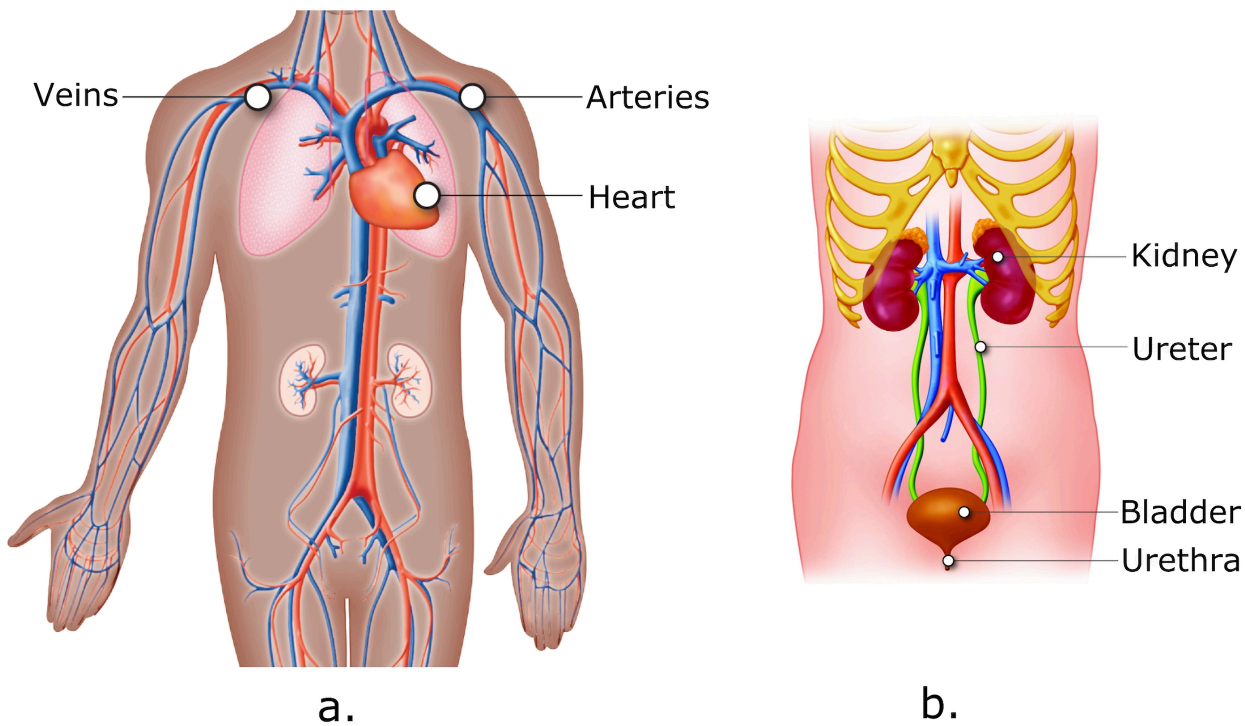


Figure 1.6. Systems Involved in Fluid Transport within the Body. a. Cardiovascular System, b. Urinary System

Single-celled organisms can directly absorb nutrients and oxygen from the environment into themselves, which they use to support essential cell functions. Single-celled organisms excrete waste products in a similar fashion. In multi-celled organisms like humans, however, most cells are not exposed directly to the outside environment. Instead, body cells rely on organ systems to transport and regulate the composition of internal fluids throughout the body. The cardiovascular system provides the "pipes" that carry blood and a pump that pushes blood. The lymphatic system returns interstitial fluid to blood. This system also participates in immune function and so will be discussed in the next section. The urinary system filters blood to regulate body fluid homeostasis, including volume, pressure, and chemical composition.

## Protection from the Environment

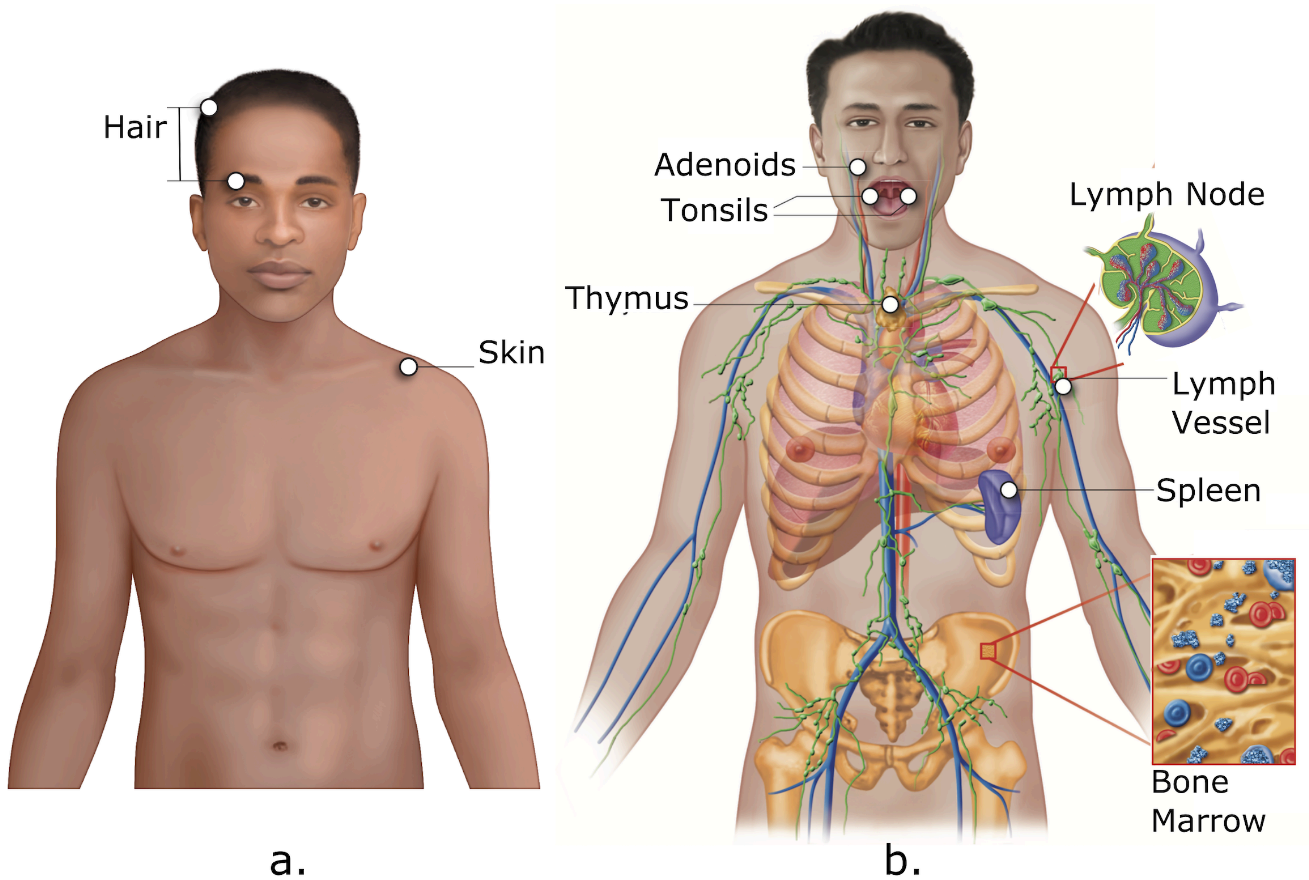


Figure 1.7. Systems that Protect the Body from the External Environment. a. Integumentary System, b. Lymphatic System

Our organs must be protected from potentially damaging environmental substances, including pathogens (disease-causing microorganisms). The integumentary system forms the immune system's first line of defense. It is made up of skin, hair, and nails. Our skin, and mucous membranes that line body cavities in contact with the environment, prevent most pathogens from entering the body and destroying healthy body cells. Organs of the lymphatic system provide the many roaming cells of the immune system with a home base. These cells, and the molecules they produce, defend us from foreign organisms that manage to enter our body tissues or fluids.

Learn By Doing 1.6

How does the body exchange with the environment? Indicate (yes or no) whether or not the functions below help the body exchange with the environment.

- Breathing?
  *Hint: Exchange with the environment involves everything that goes in and out of the body.*
- Heart Beating?
  *Hint: Exchange with the environment involves material going in or out of the body, not the transport of those items within the body.*
- Defecation?
  *Hint: Exchange with the environment involves everything that goes in and out of the body.*
- Eating and drinking?
  *Hint: Exchange with the environment involves everything that goes in and out of the body.*

What has to move or flow through the body? Indicate (yes or no) which materials are transported throughout the body.

- Water?
  *Hint: Blood flows through the body. What is the primary fluid component of blood?*
- Nutrients?
  *Hint: Materials needed throughout the body that come in at one location are transported through the body.*
- Muscles?
  *Hint: Do muscles flow throughout the body?*
- Oxygen?
  *Hint: Body processes need food and oxygen, which we get from the environment. These processes also produce waste.*
- Waste products?
  *Hint: Wastes are produced throughout the body and need to travel to places of processing before they can be excreted into the environment.*

What structure(s) is/are directly responsible for helping you stand up straight? Indicate (yes or no) whether the items below help do this as part of the vital functions of providing structure, support, and protection.

- Lungs?
  *Hint: Think of the parts of your body needed to lift something.*
- Bones?
  *Hint: Think of the parts of your body needed to lift something.*

- Stomach and intestines?
  *Hint: The digestive system brings nutrients into the body and removes undigested food.*
- Muscles?
  *Hint: Think of the parts of your body needed to lift something.*

What is the most important regulator and coordinator of multiple functions in the body?
*Hint: We consciously or unconsciously control most of our body functions with this organ.*

- stomach
- bones
- heart
- brain
- eyes

Which of the following protects our bodies from the environment? Choose all that are correct.
*Hint: Consider what things our bodies must be protected against.*

- red blood cells
- white blood cells
- internal body cavities
- skin
- lymph nodes
- mucous membranes

As you can see, several organ systems work together to accomplish vital functions throughout the body. Since the organ systems are distributed throughout large regions of the human body, it is necessary to define orientation within the body and communicate the proper terminology as you study these integrated structures and functions.

*

# “Learn By Doing” and “Did I Get This?” Feedback

**Learn By Doing 1.1**

- In your own words, describe how structure and function are related.
  *Put simply, the way something is built–the form it takes–determines its ability to perform a given task. We often say “Structure equals function.”*
- Think about your experience of the world. Give an example of the relationship between structure and function from outside biology.
  *Cooks use a variety of pots and pans; these come in a range of shapes and sizes. A tall, large pot is well-suited to cooking 2 pounds of pasta but not to frying an egg. Similarly, construction workers use a variety of tools; these come in a range of shapes and sizes. A hammer is well-suited to drive a nail into a board but would not work to tighten a bolt. Both of these examples demonstrate that the way something is structured determines its ability to perform a specific function.*

**Learn By Doing 1.2**

Diabetes Mellitus is a set of metabolic diseases wherein the body either does not produce enough of the hormone insulin or cells do not respond to the insulin that is produced. This results in high levels of sugar (glucose) in the blood. Diabetes Mellitus results from an inability to properly control the homeostasis of what?

1. insulin levels
   *Not quite. The amount of insulin itself is not necessarily the problem. Sometimes there is enough insulin, but the body cannot use it properly. Insulin levels usually control blood*

*glucose levels, but it is blood glucose levels being out of the homeostatic range that causes problems in untreated diabetes.*

2. blood pressure
   *No: Although blood pressure is a homeostatically controlled variable, it is not the problem in diabetes.*
3. blood glucose levels
   *Yes: The body tries to keep blood glucose levels between 90 and 100 mg/dl (milligrams per deciliter), but in untreated diabetes, it can be much higher than this.*
4. blood flow
   *No: Blood contains sugar, but the flow is not the culprit in this condition.*

**Learn By Doing 1.3**

Think about your experience of the world. Give an example of the hierarchical organization of a complex structure from outside biology.
*Imagine a building (top level) made of bricks, glass, and wood (all second level). Bricks are made of clay, sand, lime, iron oxide, and fly ash (fine particles of burned fuel), and water (third level). Clay itself is composed of tiny particles of weathered rocks. Clays contain kaolinite, montmorillonite-smectite, and illite minerals (fourth level). Kaolinite contains atoms of the elements oxygen, silicon, hydrogen, and aluminum (fifth level).*

Learn By Doing 1.4

Describe an example of interdependence among cells within your body.

*Our answer: There are many good answers. Your brain cells depend on freshly oxygenated blood* *flow, so if your lungs or heart stop functioning, your brain cells will die within several minutes. On the other hand, your lungs and heart work partly under the control of signals from your brain. You cannot digest food properly or make specific vitamins without help from bacteria in your gut, and these, in turn, depend on your body as a warm, nutrient-rich place to grow. Whatever example you came up with should have this sense of a two-way interaction: the cells are mutually dependent on one another.*

Learn By Doing 1.5

Think about your own body and its many functions. Which functions are essential? What functions does your body need to perform each day to survive?
***Our answer:*** *Your body performs many unique and interconnected functions that contribute to at least one of the following: 1. Exchanging material with the environment; 2. Transporting fluids and materials within the body; 3. Structure, support, and movement; 4. It regulates and controls processes; and 5. Protecting us from the environment*

Did I Get This? 1.1

Which of the following concepts would be classified as vital functions of human life?

- fluid transport within the body, and control and regulation
  *Yes: These are two of the body's vital functions. Exchange with the environment and structure, support, and movement are also vital functions.*
- homeostasis and structure and function
  *No: Homeostasis and structure and function are important organizational themes, but they apply to all of the various vital functions in the human body.*

- the nervous system and the cardiovascular system
  *No: These are organ systems that function to perform vital functions, not independent vital functions.*
- the cell is the basic unit of life
  *No: Recognizing the cell is the basic unit of life is one of the big ideas in physiology, not a vital function.*

Learn By Doing 1.6

How does the body exchange with the environment? Indicate (yes or no) whether or not the functions below help the body exchange with the environment.

- Breathing?
  *Yes: Although you cannot see an exchange taking place, breathing allows us to bring in oxygen and expel waste (carbon dioxide).*
- Heart Beating?
  *No: Although the heartbeat drives the transport of materials exchanged by the respiratory and digestive systems into or out of the blood, this body function does not directly participate in the exchange.*
- Defecation?
  *Yes: Exchanging with the environment includes getting rid of waste. Defecation removes solid, undigested waste from the digestive system.*
- Eating and drinking?
  *Yes: Both eating and drinking bring materials into the body.*

What has to move or flow through the body? Indicate (yes or no) which materials are transported throughout the body.

- Water?
  *Yes: Water is a solvent used to carry materials through the body.*
- Nutrients?

*Yes: Nutrients are needed to support a variety of functions throughout the body.*

- Muscles?
  *No: While muscles shorten and lengthen, muscles do not flow and are not transported through the body.*
- Oxygen?
  *Yes: Red blood cells carry oxygen through the body to help metabolize materials inside the body's tissues.*
- Waste products?
  *Yes: The body produces wastes, which need to be transported to centers of processing and excretion.*

What structure(s) is/are directly responsible for helping you stand up straight? Indicate (yes or no) whether the items below help do this as part of the vital functions of providing structure, support, and protection.

- Lungs?
  *No: Although the lungs bring in oxygen needed throughout the body, it is not directly responsible for you standing up straight.*
- Bones?
  *Yes: Bones provide the physical structure needed to stand up straight.*
- Stomach and intestines?
  *No: Although the digestive system brings in nutrients needed by the body, it is not directly responsible for you standing up straight.*
- Muscles?
  *Yes: Muscles provide the force needed to maintain a straight posture.*

What is the most important regulator and coordinator of multiple functions in the body?

- stomach
  *No: The stomach plays an important part in regulating the digestive system but does not regulate multiple functions within the body.*
- bones
  *No: Bones do participate in homeostasis but do not regulate multiple body functions.*
- heart
  *No: The heart is essential for transporting nutrients needed in a variety of processes but does not regulate multiple functions within the body. The nervous and endocrine systems help regulate the cardiovascular system function.*

- brain
  *Yes: We use the brain to process information and control bodily functions consciously (by making decisions) and unconsciously (with automated processes).*
- eyes
  *No: Eyes help us interact with the environment but do not regulate multiple body functions; we must process this sensory information consciously (by making decisions) and unconsciously (with automated processes) to affect other systems.*

Which of the following protects our bodies from the environment? Choose all that are correct.
*Hint: Consider what things our bodies must be protected against.*

- red blood cells
  *No: Red blood cells are responsible for oxygen transport.*
- white blood cells
  *Yes: White blood cells, and the molecules they produce, defend us from fpathogens that manage to enter our body tissues or fluids.*
- internal body cavities
  *No: Internal body cavities are not in contact with the outside environment.*
- skin
  *Yes: Skin acts as a barrier that protects us from pathogens, mechanical and chemical trauma, and dehydrating environments.*
- lymph nodes
  *Yes: Lymph nodes are one location where white blood cells called lymphocytes are presented with molecules that come from pathogens. These pathogen-derived molecules allow lymphocytes to target pathogens and to spare our own cells.*
- mucous membranes
  *Yes: Mucous membranes line the body cavities in contact with the outside world. Similar to skin, they act as barriers to pathogens and protect underlying tissues from mechanical and chemical trauma.*

## Media Attributions

- Levels of Organization in the Human Body
- Jenga
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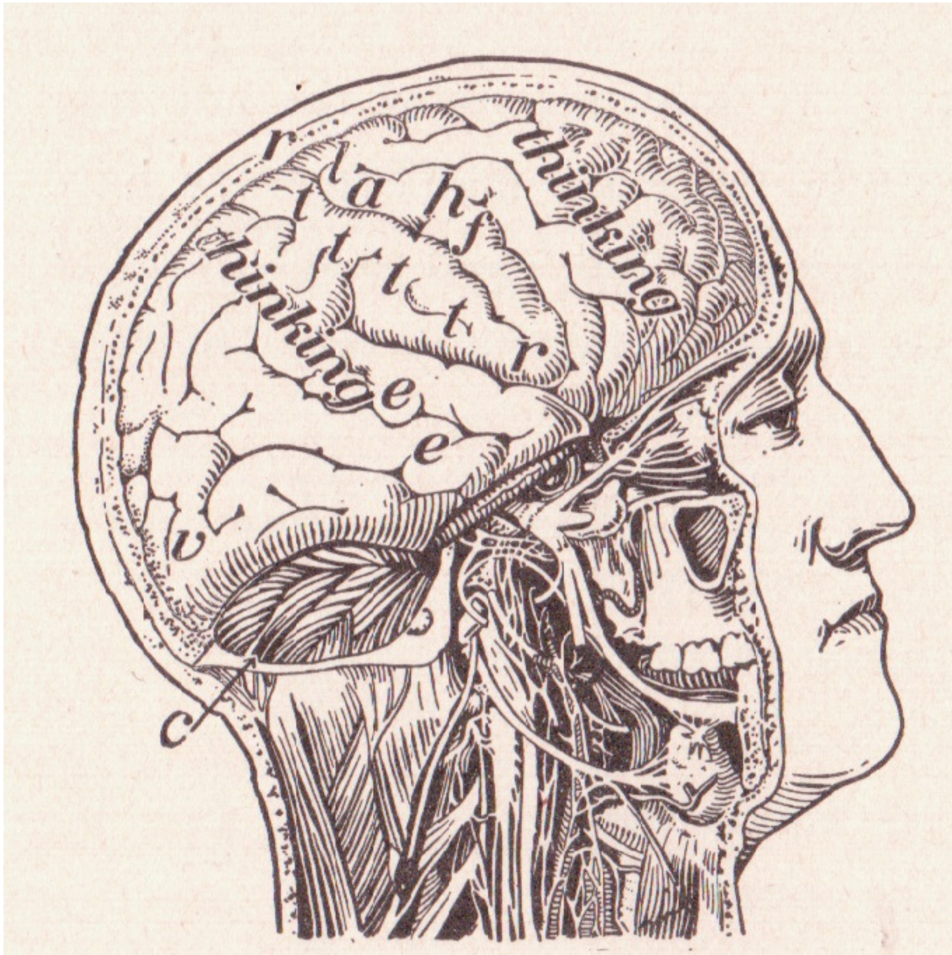
# PART II
# CONTROL AND REGULATION, AN INTRODUCTION

As you may have guessed from the previous chapter on homeostasis, two systems of the body are key to maintaining homeostasis: the endocrine and nervous systems. These systems interact, and each complements one the other's functions.

The endocrine system includes the glands of the body and the hormones that they produce. The endocrine system controls body processes through the production, secretion, and regulation of hormones, which serve as chemical "messengers" that function in coordinating cellular and organ activity. Ultimately, hormones are critical to maintaining the body's homeostasis. Many of the glands of the endocrine system are controlled by hormones released from other glands.




(From the book The Human Body and Health, Revised by Alvin Davison, 1908; CC BY)

The nervous system regulates some glands directly and others indirectly and is often referred to as the master controller of the human body. Like the endocrine system, the other internal control system of the human body, the nervous system is specialized for communication of information from one part of the body to another.We will explore the endocrine system after reviewing the structure and function of the other systems of the body, since that background is necessary to fully grasp how crucial the endocrine system is.

In this unit, we'll explore the structure and function of the nervous system. The nervous system communicates quickly using **neurons**, the specialized cells of the nervous system. Neurons can convey and process information using electrical and chemical signals. The nervous system also contains **glia**, cells that provide support functions for the neurons by playing an information processing role that is complementary to neurons. A neuron can be compared to an electrical wire—it transmits a signal from one place to another. Glia can be compared to the workers at the electric company who make sure wires go to the right places, maintain the wires, and take down wires that are broken. On the organ level, all nervous systems share a basic structure: a **central nervous system (CNS)** that contains the brain and spinal cord and a peripheral nervous system (PNS) made up of peripheral sensory and motor nerves. Ultimately, neural communication helps coordinate body activities and ensures we maintain homeostasis.

Imagine that you decide to bake a cake for a friend's birthday. You find a recipe, locate the ingredients and then one by one, measure and add each to the mixing bowl. You stir the mixture and before you know it, the cake is in the oven and you can return to your homework. You start to salivate as a yummy chocolate aroma wafts through the room. The timer goes off, but unfortunately, when removing the pan from the oven you burn your hand through a hole in the hot pad. Rather than dropping the cake, you make a split-second decision to hold on, enduring the pain so that you can set the cake pan down safely even though the consequences of a burnt hand will be with you for a few days. All aspects of baking a cake from your decision to bake a cake, to reading the recipe, measuring and mixing ingredients, smelling a delicious chocolate aroma and automatically starting to salivate in case you decide to sneak a piece of cake, and withdrawing your hand to prevent a burn are functions of the nervous system. Although quite different behaviors, they all include the general functions of the nervous system listed below:

1. *The nervous system detects changes in our internal and external environment (stimuli) using specific neurons or specialized cells communicating with neurons called* sensory receptors.
   Sensory receptors can detect a variety of different external and internal stimuli such as: skin temperature, light (for vision), sound, chemicals in food (taste) and air (smells), pressure, pain, blood pH, core body temperature, bladder distension as well as many other stimuli.
2. *Sensory receptors transform stimuli into electric signals that our nervous system can understand.*
   The nervous system cannot directly interpret stimuli like light, heat or sound. The information has to be transformed into an electrical signal for the nervous system to receive and process the information.
3. *Sensory neurons transmit the electrical signals from the periphery to the central nervous system (brain and spinal cord).*
   This information travels from the sensory receptor (the site of transformation) along neural processes called axons towards the central nervous system (CNS).
4. *The central nervous system (brain and spinal cord) processes incoming sensory information to generate "appropriate" responses and also to give us the perception of the stimulus.*
   The signal can be compared to a normal value (set point) or related to past experiences to determine if the stimulus requires a response. Processing of the signal is called **integration**. In order to perceive a stimulus, the sensory information must be transmitted to specific areas of the brain.
5. *The central nervous system sends commands (electrical signals passed along neurons) out to the target tissues to produce the response.*
   The target tissues of the nervous system are muscles and glands.

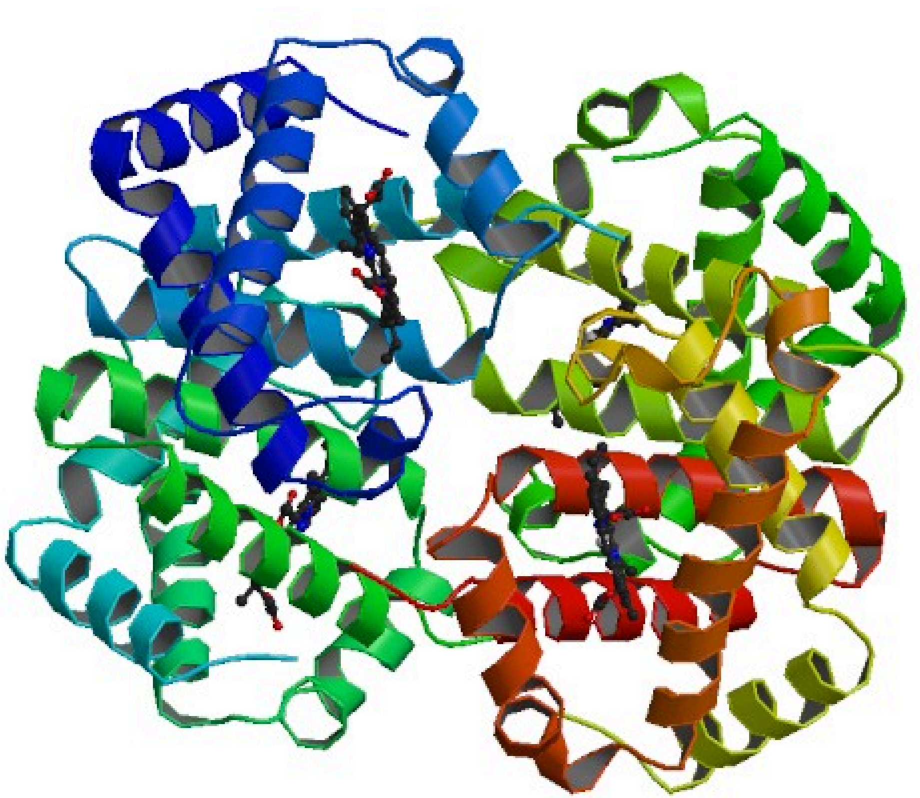
Even fundamental functions, like breathing and regulation of body temperature, are controlled by the nervous system. A nervous system is an organism's control center: it processes sensory information from outside (and inside) the body and controls all behaviors—from baking to eating to learning to sleeping to finding a mate.

## Media Attributions

- old brain 2

# PART II
# LEVELS OF ORGANIZATION

**Introduction to the Unit**



3 Dimensional Model of Hemoglobin

What do you see when you look at this picture? Is it just a mass of tangled ribbons? Look closely. It is actually a complex pattern of three-dimensional shapes. It represents the structure of a common chemical found inside living cells. The chemical is a protein called hemoglobin. This protein in red blood cells transports oxygen around the body.

What are proteins? What other chemicals are found in living things? You will learn the answers to these questions as you read about biochemistry– the chemistry of life.

Life is a complex continuum of flows of energy and matter. Discrete structures such as organs and cells allow us to divide life into levels of organization. This organization is, to some extent, artificial and, to some extent, practical.

The human body is a complex, hierarchical system—that is, a system made up of smaller subsystems, which are themselves made up of even smaller systems. We commonly study these different hierarchical levels—levels of organization—separately. By breaking down the complex system into simpler parts, we can make the whole system easier to understand. This "reductionist" approach, reducing a complex system to simpler components, is central to how we practice modern science.

Therefore, we consider the body as a whole, then its subsystems, and then the components of these subsystems. We can model the organizational hierarchy within the body as comprised of organs, tissues, cells, cell organelles, macromolecules, molecules, and atoms.

The levels of organization that we will consider in this course are, from smallest to largest:

- The chemical level, which consists of atoms, ions, and small molecules
- The macromolecule level, which consists of large molecules
- The cell level, which consists of individual cells, is the smallest level that contains living entities
- The tissue level, which consists of groups of related cells working together to perform a specific function
- The organ level, which consists of groups of tissues working together to perform a higher-level function
- The organ system level, which includes all of the organs involved in performing a vital function
- The organism or whole-body level, which consists of a whole person
- The population or environment level, which involves the interactions of the person with their environment

Although we will consider each level individually, you must remember the connections between the levels. Processes and events at one level can affect other levels. An alteration in the structure of a protein (macromolecule level) can prevent a cell from functioning properly; this improper function can affect the tissues, organs, organ systems, and the whole body. And the reverse is true: changes to the body (organism level) can affect organs, tissues, cells, and molecules.

For example, suppose a single nitrogen-containing base in DNA (chemical level) is incorrect. This mutation causes an alteration in the structure of the beta-globin (β-globin) protein (macromolecule level), which is part of hemoglobin. The altered structure of β-globin causes the proteins to stick together and form fiber-like structures. Under certain physiological conditions, the fibers distort the shape of red blood cells (cell level), so the cells become curved and twisted. The abnormal cells get stuck in capillaries, reducing blood flow to tissues and organs (tissue and organ levels). Organ damage can result and permanently affect body function (whole-body level).

This example describes sickle cell anemia, a genetic blood disorder. We can clearly see the connections between levels of organization. A seemingly tiny error at the genetic (chemical) level causes significant changes in the body's systems at higher levels. Many genetic diseases arise this way—through slight alterations in the genetic code.

But scientists are homing in on the genetic basis for some diseases, such as cancer. In some instances, our understanding may hint at genetic therapies for disease. Such technology is still largely experimental, but it shows the practical value of looking at the levels of organization of complex systems.

At every level of organization, structure is related to function. For example, water can perform many of its unique and life-sustaining properties because of its structure. It is a bent polar molecule that can form attractions with neighboring water molecules through hydrogen bonds. At the macromolecular level, the unique structures of enzymes allow these proteins to help speed up reactions. On the cell and tissue level, the rigid matrix structure of your bones enables them to support your body's weight. At the organ level, the "J" shape of the stomach allows for partial segregation of its contents at the early stages of digestion.

## Media Attributions

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# PART II
# SUPPORT SYSTEMS OF THE BODY

The muscular, skeletal, and integumentary systems have been grouped together as the "support systems." Remember, this isn't a hard-and-fast categorization: these systems are grouped together to help you organize your learning. These support systems provide the structure (and support!) for your body: your muscles, skeleton, and skin.

The **skeletal system** not only helps to provide movement and support but also serves as a storage area for calcium and inorganic salts and a source of blood cells. The adult human body has 206 bones in a variety of shapes and sizes. There are also 2 types of bone tissue in different amounts in bones.

A skeleton in a classical landscape. Drawing by Auguste Joron, 1810. Credit: Wellcome Library, London.

The **muscular system** is the biological system of humans that produces movement. The muscular system, in vertebrates, is controlled through the nervous system, although some muscles, like cardiac muscle, can be completely autonomous. **Muscle** is contractile tissue and is derived from the mesodermal layer of embryonic germ cells. Its function is to produce force and cause motion, either locomotion or movement within internal organs. Much of muscle contraction occurs without conscious thought and is necessary for survival, like the contraction of the heart or peristalsis, which pushes food through the digestive system. Voluntary muscle contraction is used to move the body and can be finely controlled, such as movements of the finger or gross movements like those of the biceps and triceps.

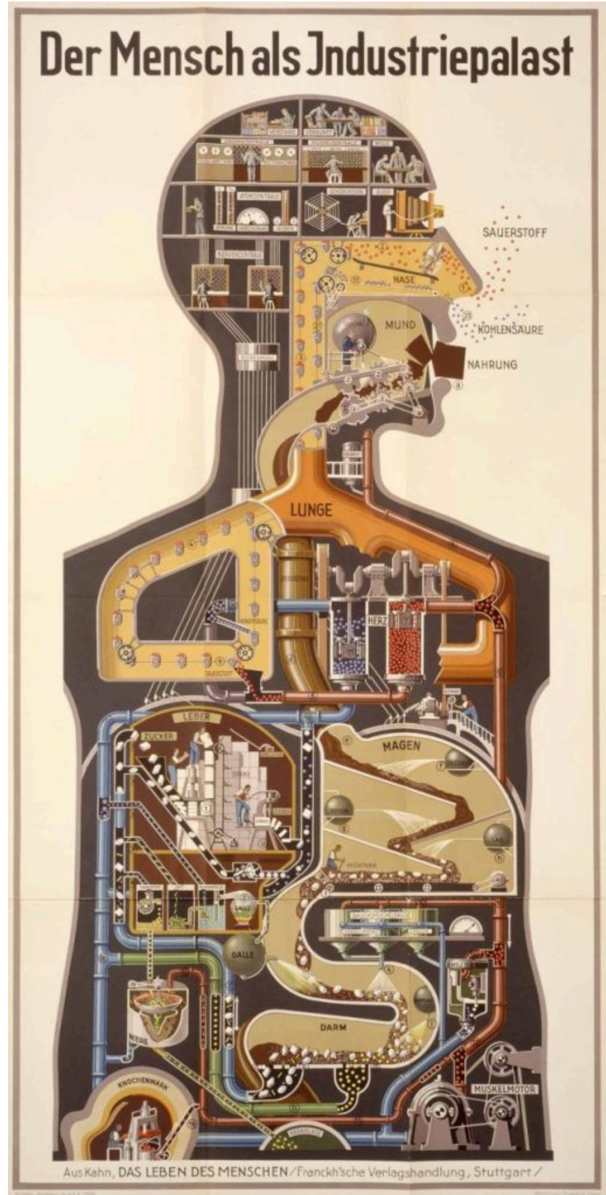
## Media Attributions

- L0027182 A skeleton in a classical landscape. Drawing by A. Joron.

# PART II
# EXCHANGE WITH THE ENVIRONMENT

*One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.pub/humanbiology/?p=304#oembed-1*

As you likely know, humans take in food, water, and oxygen. Human cells require nutrients to use as a source of energy and as the building blocks of more complex molecules. Our cells also need oxygen in order to access most of the energy in nutrients. These chemical reactions are part of metabolism. And as you've learned, metabolism generates waste products that must be disposed of. The waste products of digestion and metabolism include solid waste, liquid waste, and carbon dioxide. These waste materials must be eliminated from the body to maintain homeostasis.




Man as Industrial Palace (Der Mensch als Industriepalast) Stuttgart, 1926. Chromolithograph. National Library of Medicine.

Both the intake of needed materials and the excretion of waste are accomplished by the transport of molecules across the cell membrane. For individual single-celled organisms, this process is fairly simple since they are in direct exchange with the environment. In multicellular organisms, however, the process is more complicated since most of our cells are not in direct contact with the "outside" environment. Because of this, we use specialized organ systems that serve as exchange zones with the environment, moving things into and out of the body to keep it functioning. The two major organ systems that exchange nutrients and waste with the environment are the digestive system (food and feces) and the respiratory system (oxygen and carbon dioxide). (The urinary system also helps with the removal of metabolic wastes that are transported in body fluids, but the "exchange" is all internal, so it will be explored further in the next section of the book, Transport of Fluids.)

As you read the chapters on the digestive and respiratory systems, keep in mind the ultimate purpose of these systems– to import materials critical to maintaining the health and functioning of our cells and to excrete materials that would cause damage should they be retained. These chapters will draw heavily on your understanding of cell transport mechanisms, so review that part of the cell chapter before you begin reading.

For your enjoyment: The intertwining of science, art, and technology: An animated and interactive installation based on the poster of the same title by Fritz Kahn from 1927. Physician, writer, and artist Fritz Kahn

(1888–1968) explored the relationship between man and machine: “[they] exhibit far-reaching similarities. Both derive their energy from the combustion of carbon, which they obtain from plants. Man, the weaker machine, utilizes fresh plants for fuel, while the locomotive, a stronger machine, uses fossilized plants in the form of coal.”

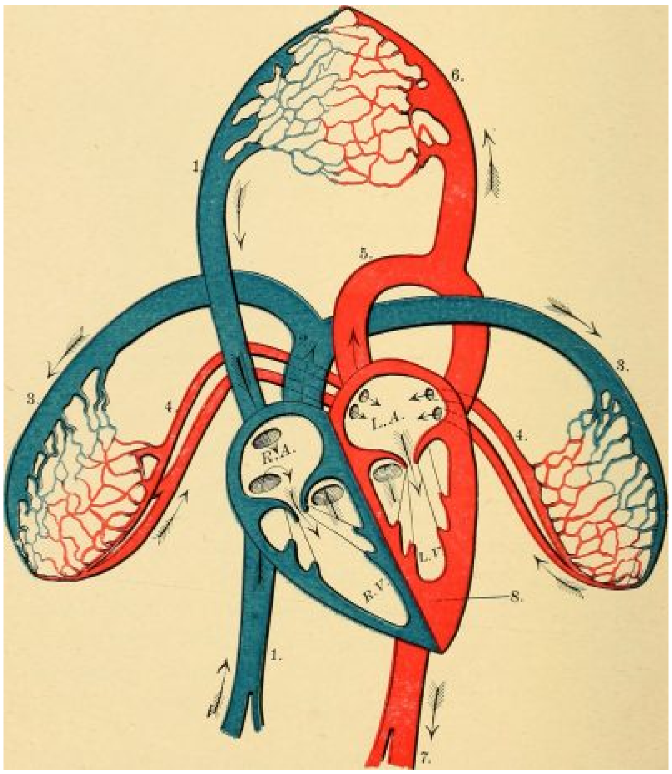
https://youtube.com/watch?v=PfBaAnJ1A4s

Concept, interaction & animation: Henning M. Lederer Sound-Design: David Indge © Henning M. Lederer 2011

## Media Attributions

- fritz-kahn-1930-poster-x640

# PART II
# TRANSPORT OF FLUIDS WITHIN THE BODY




Diagrammatic Representation of the Circulation through the Heart and Body
(Credit: Jerome Walker, 1900; Public Domain)

Thus far we have discussed systems that support the body and allow movement, and systems that allow us to obtain needed materials from the environment. Now we turn our attention to the systems of the body that allow us to transport materials such as oxygen, nutrients, and water. You may have guessed that we will investigate the structure and function of the **cardiovascular system** (CVS), which includes the heart, blood vessels, and blood. We will also explore the **lymphatic system**, which is sometime described as the little-known cousin of the CVS. This system should not be underestimated, however. As you've learned, no lipids can be absorbed from our food without specialized lymphatic capillaries called lacteals. In addition, the lymphatic system has two other critical roles. The first involves returning fluid to the bloodstream after the process of capillary exchange. The second involves providing a "home base" for the **immune system**, and this function will be explored in a later section of the text.. In this section of the text we will also investigate the **urinary system**. This system might have also been included in section of the book dealing with exchange with the environment, since part of the urinary system's functioning involves, well, urination. It has been included here to emphasize that this system's primary role is to filter metabolic waste out of the blood; urine is simply filtered blood.

## Media Attributions

- heart circulation

# PART II
# PROTECTION FROM PATHOGENS

Viral Infection (2002) – Video Installation, Irvine, CA by Jason Watanabe (CC BY-SA 4.0)

Despite relatively constant exposure to disease-causing microbes in the environment, humans do not generally suffer from constant infection or disease. Many systems of the body participate in protecting our bodies from pathogens. Here we will explore how the Integumentary, Lymphatic, and Immune Systems ensure the integrity of our bodies.

Before any immune factors are triggered, the integument or skin functions as a continuous, impassable barrier to potentially infectious pathogens. Pathogens are killed or inactivated on the skin by desiccation (drying out) and by the skin's acidity. In addition, beneficial microorganisms that coexist on the skin compete with invading pathogens, preventing infection.

Under most circumstances, the body is able to defend itself from the threat of infection thanks to a complex immune system designed to repel, kill, and expel disease-causing invaders. Immunity as a whole can be described as two interrelated parts: nonspecific innate immunity and specific adaptive defenses. The nonspecific innate immune response provides a first line of defense that can often prevent infections from gaining a solid foothold in the body. These defenses are described as nonspecific because they do not target any specific pathogen; rather, they defend against a wide range of potential pathogens. They are called innate because they are built-in mechanisms of the human organism. Unlike the specific adaptive defenses, they are not acquired over time and they have no "memory" (they do not improve after repeated exposures to specific pathogens). Specific adaptive immunity is acquired through active infection or vaccination and serves as an important defense against pathogens that evade the defenses of innate immunity. Adaptive immunity is defined by two important characteristics: specificity and memory. Specificity refers to the adaptive immune system's ability to target specific pathogens, and memory refers to its ability to quickly respond to pathogens to which it has previously been exposed.

## Media Attributions

- 1024px-Viral_Infection_(2002)

# PART II
# CONTROL AND REGULATION 2

Communication is a process in which a sender transmits signals to one or more receivers to control and coordinate actions. In the human body, two major organ systems participate in relatively "long distance" communication: the nervous system and the endocrine system. Together, these two systems are primarily responsible for maintaining homeostasis in the body.

## Neural and Endocrine Signaling

The nervous system uses two types of intercellular communication—electrical and chemical signaling—either by the direct action of an electrical potential, or in the latter case, through the action of chemical neurotransmitters such as serotonin or norepinephrine. Neurotransmitters act locally and rapidly. When an electrical signal in the form of an action potential arrives at the synaptic terminal, they diffuse across the synaptic cleft (the gap between a sending neuron and a receiving neuron or muscle cell). Once the neurotransmitters interact (bind) with receptors on the receiving (post-synaptic) cell, the receptor stimulation is transduced into a response such as continued electrical signaling or modification of cellular response. The target cell responds within milliseconds of receiving the chemical "message"; this response then ceases very quickly once the neural signaling ends. In this way, neural communication enables body functions that involve quick, brief actions, such as movement, sensation, and cognition. In contrast, the **endocrine system** uses just one method of communication: chemical signaling. These signals are sent by **endocrine glands**, which secrete chemicals—**hormones**—into the extracellular fluid. Hormones are transported primarily via the bloodstream throughout the body, where they bind to receptors on target cells, inducing a characteristic response. As a result, endocrine signaling requires more time than neural signaling to prompt a response in target cells, though the precise amount of time varies with different hormones. For example, the hormones released when you are confronted with a dangerous or frightening situation, called the fight-or-flight response, occur by the release of adrenal hormones—epinephrine and norepinephrine—within seconds. In contrast, it may take up to 48 hours for target cells to respond to certain reproductive hormones.

In addition, endocrine signaling is typically less specific than neural signaling. The same hormone may play a role in a variety of different physiological processes depending on the target cells involved. For example, the hormone oxytocin promotes uterine contractions in women in labor. It is also important in breastfeeding, and may be involved in the sexual response and in feelings of emotional attachment in both males and females.

In general, the nervous system involves quick responses to rapid changes in the external environment, and the endocrine system is usually slower acting—taking care of the internal environment of the body, maintaining homeostasis, and controlling reproduction (see table below). So how does the fight-or-flight response that was mentioned earlier happen so quickly if hormones are usually slower acting? It is because the two systems are connected. It is the fast action of the nervous system in response to the danger in the environment that stimulates the adrenal glands to secrete their hormones. As a result, the nervous system can cause rapid endocrine responses to keep up with sudden changes in both the external and internal environments when necessary.

**Endocrine and Nervous Systems**

| | **Endocrine system** | **Nervous system** |
|---|---|---|
| Signaling mechanism(s) | Chemical | Chemical/electrical |
| Primary chemical signal | Hormones | Neurotransmitters |
| Distance traveled | Long or short | Always short |
| Response time | Fast or slow | Always fast |
| Environment targeted | Internal | Internal and external |

# PART II
# REVIEW AND SYNTHESIS: PUTTING IT ALL TOGETHER

In the introductory units we covered the major themes of Human Biology, and we have addressed these themes as they relate to each specific organ system. In this review and synthesis unit we will present specific examples of how these themes relate to every aspect of physiology. We will present examples specific to different organ system units to review both the major themes and your understanding of the different organ systems.

In this section we will also examine pathological conditions related to Human Biology, focusing on two conditions: sickle cell anemia and obesity. Sickle cell anemia is a genetic disease that impacts specific populations. This condition is present at birth and is present throughout the individual's lifetime. On the other side of the spectrum, is obesity. Although there are some genetic factors which influence obesity, usually environmental and psychological factors are as much to blame for the pathologies associated with obesity.

Through these examples of physiology and pathology, we will examine Human Biology as it relates to structure and function, levels of organization, homeostasis, and integration of systems.