"The Human Organism" An Instructional Material in Anatomy and Physiology

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INTRODUCTION

Welcome to the study of one of the most fascinating subjects possible—your own body. Such a study is not only highly personal, but timely as well. We get news of some medical advance almost daily. To appreciate emerging discoveries in genetic engineering, to understand new techniques for detecting and treating disease, and to make use of published facts on how to stay healthy, you'll find it helpful to learn about the workings of your body. If you are preparing for a career in the health sciences, the study of anatomy and physiology has added rewards because it provides the foundation needed to support your clinical experiences.

Knowing human anatomy and physiology is also the basis for understanding disease. The study of human anatomy and physiology is important for you students who plan a career in the health sciences because health professionals need a sound knowledge of structure and function in order to perform their duties. In addition, understanding anatomy and physiology prepares all of us to evaluate recommended treatments, critically review advertisements and reports in the popular literature, and rationally discuss the human body with health professionals and non-professionals.

What lies ahead is an astounding adventure—learning about the structures and functions of the human body and the intricate checks and balances that regulate it. In this module we define and contrast anatomy and physiology and discuss how the human body is organized. Then we review needs and functional processes common to all living organisms. Three essential concepts—the complementarity of structure and function, the hierarchy of structural organization, and homeostasis—will unify and form the bedrock for your study of the human body. The final section of the module deals with the language of anatomy—terminology that anatomists use to describe the body or its parts .I welcome you all to the exciting and challenging study of human anatomy and physiology!

1. ANALYSIS

In doing this activity what have you grasped? Louie's response to eating the energy bar is a good example of how important this system of checks and balances is in the body. Perhaps you have had a similar experience, but with a different outcome. You have overslept, rushed to prepare for your 8 a.m. class via zoom meeting, and missed breakfast. Afterwards, while having on-line Anatomy & Physiology class, you grabbed an energy bar from the pantry. Eating the energy bar helped you feel better. The explanation for these experiences is the process of homeostasis; for you, homeostasis was maintained, but for Louie, there was a disruption in homeostasis. Throughout this book, the major underlying theme is homeostasis. As you think about Louie's case, you will come to realize just how capable the human body is of an incredible coordination of thousands upon thousands of processes.

2. ABSTRACTION

Key Terms:

Anatomy - is the scientific discipline that investigates the body's structure—for example, the shape and size of bones.

Physiology - is the scientific investigation of the processes or functions of living things.

Cells - are the basic structural and functional units of plants and animals.

Tissue - is composed of a group of similar cells and the materials surrounding them.

Organ - is composed of two or more tissue types that perform one or more common functions.

Homeostasis - is the existence and maintenance of a relatively constant environment within the body.

Anatomical position - refers to a person standing erect with the face directed forward, the upper limbs hanging to the sides, and the palms of the hands facing forward.

Directional terms - describe parts of the body relative to each other.

Plane - divides, or sections, the body, making it possible to "look inside" and observe the body's structures.

You are about to embark on an adventure into the amazing world of human anatomy and physiology. Both fields explore the incredible workings of the human body.

Now let's keep the ball rolling!

Two complementary branches of science—anatomy and physiology—provide the concepts that help us to understand the human body.

Anatomy and Physiology

1. Anatomy is the study of the body's structures.
   - Developmental anatomy considers anatomical changes from conception to adulthood. Embryology focuses on the first 8 weeks of development.
   - Cytology examines cells, and histology examines tissues.
   - Gross anatomy studies organs from either a systemic or a regional perspective.
   - Surface anatomy uses superficial structures to locate deeper structures, and anatomical imaging is a non-invasive technique for identifying deep structures.
2. Physiology is the study of the body's functions. It can be approached from a cellular or a systems point of view. Physiology is the scientific investigation of the processes or functions of living things. The major goals when studying human physiology are to understand and predict the body's responses to stimuli and to understand how the body maintains conditions within a narrow range of values in a constantly changing environment. Like anatomy, physiology can be considered at many levels.
   - Cell physiology examines the processes occurring in cells, and systemic physiology considers the functions of organ systems.
   - Neurophysiology focuses on the nervous system, and cardiovascular physiology deals with the heart and blood vessels.

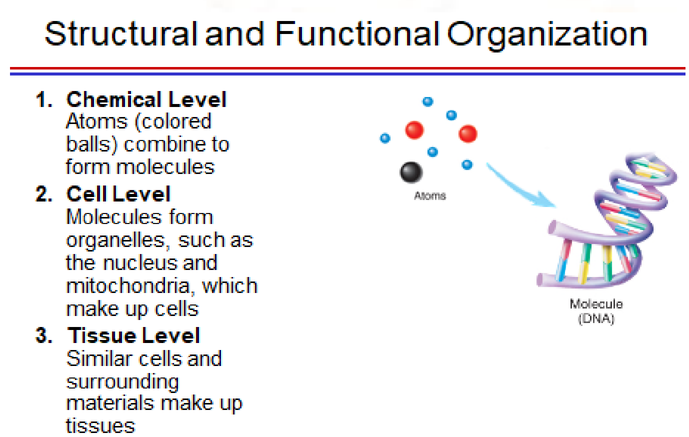
Physiology often examines systems rather than regions because a particular function can involve portions of a system in more than one region. Studies of the human body must encompass both anatomy and physiology because structures, functions, and processes are interwoven.

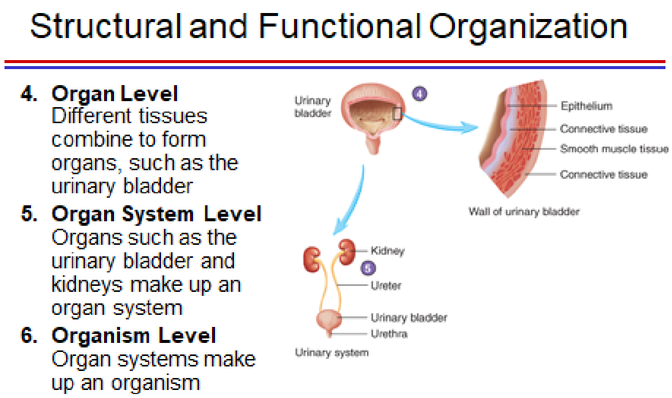
3. Pathology is the medical science dealing with all aspects of disease, with an emphasis on the cause and development of abnormal conditions, as well as the structural and functional changes resulting from disease. Exercise physiology focuses on the changes in function and structure caused by exercise.

Structural and Functional Organization of the Human Body

Scientists group the body's components into an organizational hierarchy of form and function. In thinking about these levels, it is helpful to know the characteristics common to living things and how each organizational level supports these characteristics. For example, the organ system concept allows functions to be considered as an interaction between many organs.

Before you begin to study the different structures and functions of the human body, it is helpful to consider its basic architecture; that is, how its smallest parts are assembled into larger structures. It is convenient to consider the structures of the body in terms of fundamental levels of organization that increase in complexity: subatomic particles, atoms, molecules, organelles, cells, tissues, organs, organ systems, organisms and biosphere.





Basic chemical characteristics are responsible for the structure and functions of life.

The body can be studied at six levels of organization: the chemical, cell, tissue, organ, organ system, and whole organism levels:

1. Chemical level. The chemical level involves interactions between atoms, which are tiny building blocks of matter. Atoms combine to form molecules, such as water, sugar, fats, and proteins. The function of a molecule is intimately related to its structure. For example, collagen molecules are rope-like protein fibers that give skin structural strength and flexibility. With old age, the structure of collagen changes, and the skin becomes fragile and more easily torn. We present a brief overview of chemistry in chapter 2.
2. Cell level. Cells are the basic structural and functional units of plants and animals. Molecules combine to form organelles (little organs), which are the small structures that make up cells. For example, the nucleus is an organelle that contains the cell's hereditary information, and mitochondria are organelles that manufacture adenosine triphosphate (ATP), a molecule cells use for energy. Although cell types differ in their structure and function, they have many characteristics in common. Knowledge of these characteristics, as well as their variations, is essential to understanding anatomy and physiology. We discuss the cell in chapter 3.
3. Tissue level. A tissue is composed of a group of similar cells and the materials surrounding them. The characteristics of the cells and surrounding materials determine the functions of the tissue. The numerous tissues that make up the body are classified into four basic types: epithelial, connective, muscle, and nervous. We discuss tissues in chapter 4.
4. Organ level. An organ is composed of two or more tissue types that perform one or more common functions. The urinary bladder, heart, stomach, and lung are examples of organs.
5. Organ system level. An organ system is a group of organs that together perform a common function or set of functions and are therefore viewed as a unit. For example, the urinary system consists of the kidneys, ureter, urinary bladder, and urethra. The kidneys produce urine, which the ureters transport to the urinary bladder, where it is stored until being eliminated from the body through the urethra. In this text, we consider 11 major organ systems: the integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, and reproductive systems.

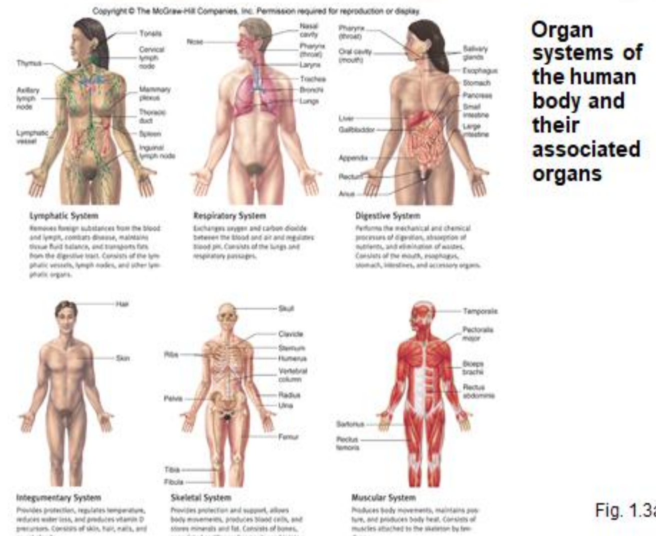


Fig. 1.3a

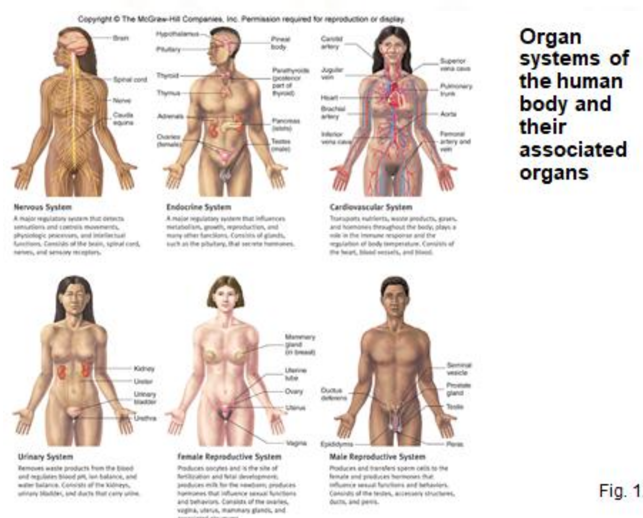


Fig. 1.3b

6. Organism level. An organism is any living thing considered as a whole—whether composed of one cell, such as a bacterium, or of trillions of cells, such as a human. The human organism is a

complex of organ systems, all mutually dependent on one another.

Characteristics of Life

Now that you know the structural levels of the human body, the question that naturally follows is: What does this highly organized human body do? Humans are organisms, sharing characteristics with other organisms. The most important common feature of all organisms is life. This text recognizes six essential characteristics of life:

1. Organization refers to the specific interrelationships among the parts of an organism and how those parts interact to perform specific functions. Living things are highly organized. All organisms are composed of one or more cells. Cells in turn are composed of highly specialized organelles, which depend on the precise organization of large molecules. Disruption of this organized state can result in loss of functions, or even death.
2. Metabolism refers to all of the chemical reactions taking place in an organism. It includes an organism's ability to break down food molecules, which the organism uses as a source of energy and raw materials to synthesize its own molecules. Energy is also used when one part of a molecule moves relative to another part, changing the shape of the molecule. Changes in molecular shape can lead to changes in cellular shape, which can produce movement of the organism. Metabolism is necessary for vital functions, such as responsiveness, growth, development, and reproduction.
3. Responsiveness is an organism's ability to sense changes in its external or internal environment and adjust to those changes. Responses include such actions as moving toward food or water and moving away from danger or poor environmental conditions. Organisms can also make adjustments that maintain their internal environment. For example, if the external environment causes the body temperature to rise, sweat glands produce sweat, which can lower body temperature back toward its normal range.
4. Growth refers to an increase in the size or number of cells, which produces an overall enlargement of all or part of an organism. For example, a muscle enlarged by exercise is composed of larger muscle cells than those of an untrained muscle, and the skin of an adult has more cells than the skin of an infant. An increase in the materials surrounding cells can also contribute to growth. For instance, bone grows because of an increase in cell number and the deposition of mineralized materials around the cells.
5. Development includes the changes an organism undergoes through time, beginning with fertilization and ending at death. The greatest developmental changes occur before birth, but many changes continue after birth, and some go on throughout life. Development usually involves growth, but it also involves differentiation and morphogenesis. Differentiation is change in cell structure and function from generalized to specialized, and morphogenesis is change in the shape of tissues, organs, and the entire organism. For example, following fertilization, generalized cells specialize to become specific cell types, such as skin, bone, muscle, or nerve cells. These differentiated cells form the tissues and organs.
6. Reproduction is the formation of new cells or new organisms. Without reproduction of cells, growth and development are not possible. Without reproduction of organisms, species become extinct.

Biomedical Research

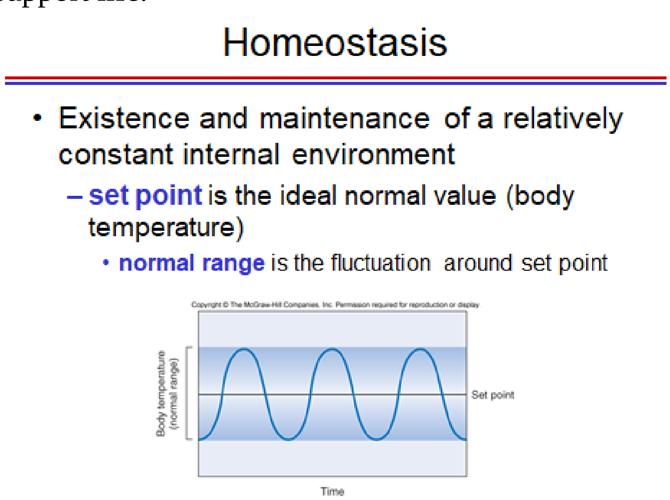
Much of our knowledge about humans is derived from research on other organisms. Studying other organisms has increased our knowledge about humans because humans share many characteristics with other organisms. For example, studying single-celled bacteria provides much information about human cells. However, some biomedical research cannot be accomplished using single-celled organisms or isolated cells. Sometimes other mammals must be studied, as evidenced by the great progress in open heart surgery and kidney transplantation made possible by perfecting surgical techniques on other mammals before attempting them on humans. Strict laws govern the use of animals in biomedical research; these laws are designed to ensure minimal suffering on the part of the animal and to discourage unnecessary experimentation.

Although much can be learned from studying other organisms the ultimate answers to questions about humans can be obtained only from humans because other organisms differ from humans in significant ways. A failure to appreciate the differences between humans and other animals led to many misconceptions by early scientists. One of the first great anatomists was a Greek physician, Claudius Galen (ca. 130–201). Galen described a large number of anatomical structures supposedly present in humans but observed only in other animals. For example, he described the liver as having five lobes. This is true for rats, but not for humans, who have four-lobed livers. The errors introduced by Galen persisted for more than 1300 years until a Flemish anatomist, Andreas Vesalius (1514–1564), who is considered the first modern anatomist, carefully examined human cadavers and began to correct the textbooks. This example should serve as a word of caution: Some current knowledge in molecular biology and physiology has not been confirmed in humans.

Homeostasis

When you think about the fact that your body contains trillions of cells in nearly constant activity, and that remarkably little usually goes wrong with it, you begin to appreciate what a marvellous machine your body is. Walter Cannon, an American physiologist of the early twentieth century, spoke of the "wisdom of the body," and he coined the word homeostasis to describe its ability to maintain relatively stable internal conditions even though the outside world changes continuously.

Homeostasis is the condition in which body functions, body fluids, and other factors of the internal environment are maintained at levels suitable to support life.



Negative Feedback

1. Negative-feedback mechanisms maintain homeostasis.
2. Many negative-feedback mechanisms consist of a receptor, a control center, and an effector.

Most systems of the body are regulated by negative-feedback mechanisms, which maintain homeostasis. Negative means that any deviation from the set point is made smaller or is resisted; therefore, in a negative-feedback mechanism, the response to the original stimulus results in deviation from the set point, becoming smaller. An example of important negative-feedback mechanisms in the body are those maintaining normal blood pressure. Normal blood pressure is critical to our health because blood pressure helps move blood from the heart to tissues. The blood transports essential materials to and from the tissues. Because a disruption of normal blood pressure could result in a disease state, maintaining homeostasis through negative feedback is a critical activity. Most negative feedback mechanisms have three components: (1) a receptor, which monitors the value of a variable; (2) a control center, which receives information about the variable from the receptor, establishes the set point, and controls the effector; and (3) an effector, which produces responses that change the value of the variable. A changed variable is a stimulus because it initiates a homeostatic mechanism. Several negative-feedback mechanisms regulate blood pressure. Here we describe one of them: Receptors that monitor blood pressure are located within large blood vessels near the heart and the head. A control center in the brain receives signals sent through nerves from the receptors. The control center evaluates the information and sends signals through nerves to the heart. The heart is the effector, and the heart rate increases or decreases in response to signals from the brain. If blood pressure increases slightly, receptors detect that change and send the information to the control center in the brain. The control center causes the heart rate to decrease, lowering blood pressure. If blood pressure goes down slightly, the receptors inform the control center, which elevates the heart rate, thereby producing an increase in blood pressure). As a result, blood pressure constantly rises and falls within a normal range of values.

Although homeostasis is the maintenance of a normal range of values, this does not mean that all variables remain within the same narrow range of values at all times. Sometimes a deviation from the usual range of values can be beneficial. For example, during exercise the normal range for blood pressure differs from the range under resting conditions and the blood pressure is significantly elevated. Muscle cells require increased oxygen and nutrients and increased removal of waste products to support their heightened level of activity during exercise. Elevated blood pressure increases delivery of blood to muscles during exercise, thereby increasing the delivery of oxygen and nutrients and the removal of waste products—ultimately maintaining muscle cell homeostasis.

Positive Feedback

1. Positive-feedback mechanisms usually result in deviations further from the set point.
2. Although a few positive-feedback mechanisms are normal for maintaining homeostasis in the body, some positive-feedback mechanisms can be harmful.
3. Normal positive-feedback mechanisms include blood clotting and childbirth labor. Harmful positive-feedback examples include decreased blood flow to the heart.

Positive-feedback mechanisms occur when a response to the original stimulus results in the deviation from the set point becoming even greater. At times, this type of response is required to re-achieve homeostasis. For example, during blood loss, a chemical responsible for blood clot formation, called thrombin, stimulates production of even more thrombin. In this way, a disruption in homeostasis is resolved through a positive feedback mechanism. What prevents the entire vascular system from clotting? The clot formation process is self-limiting. Eventually, the components needed to form a clot will be depleted in the damaged area and no more clot material can be formed. Birth is another example of a normally occurring positive feedback mechanism. Near the end of pregnancy, the baby's larger size stretches the uterus. This stretching, especially around the opening of the uterus, stimulates contractions of the uterine muscles. The uterine contractions push the baby against the opening of the uterus and stretch it further. This stimulates additional contractions, which result in additional stretching. This positive-feedback sequence ends only when the baby is delivered from the uterus and the stretching stimulus is eliminated.

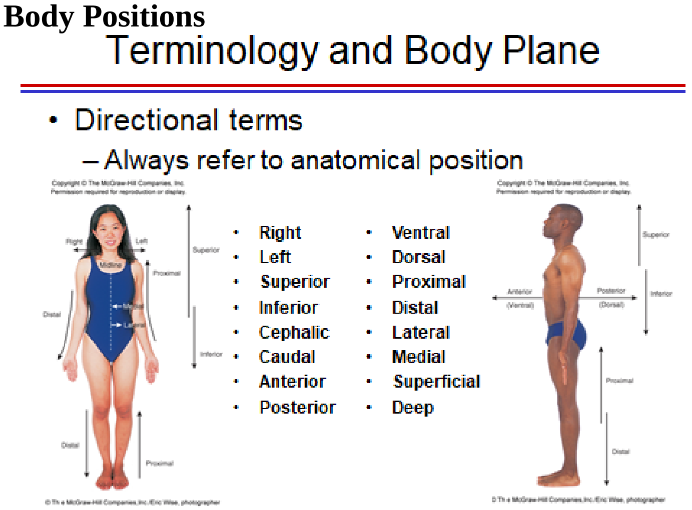
Two basic principles to remember are that (1) many disease states result from the failure of negative-feedback mechanisms to maintain homeostasis and (2) some positive-feedback mechanisms can be detrimental instead of helpful. One example of a detrimental positive-feedback mechanism is inadequate delivery of blood to cardiac (heart) muscle. Contraction of cardiac muscle generates blood pressure and the heart pumps blood to itself through a system of blood vessels on the outside of the heart. Just as with other tissues, blood pressure must be maintained to ensure adequate delivery of blood to the cardiac muscle. Following extreme blood loss, blood pressure decreases to the point that the delivery of blood to cardiac muscle is inadequate. As a result, cardiac muscle does not function normally. The heart pumps less blood, which causes the blood pressure to drop even further—a deviation further from the setpoint. The additional decrease in blood pressure further reduces blood delivery to cardiac muscle, and the heart pumps even less blood, which again decreases the blood pressure. The process self-propagates until the blood pressure is too low to sustain the cardiac muscle, the heart stops beating, and death results. In this example, we see the deviation from the heart rate set point becoming larger and larger—this is a positive- feedback mechanism. Thus, if blood loss is severe, negative-feedback mechanisms may not be able to maintain homeostasis, and the positive feedback of ever-decreasing blood pressure can develop. On the other hand, following a moderate amount of blood loss (e.g., after donating a pint of blood), negative-feedback mechanisms result in an increase in heart rate, which restores blood pressure.

Terminology and the Body Plan

Most of us are naturally curious about our bodies, but our interest sometimes dwindles when we are confronted with the terminology of anatomy and physiology. Let's face it—you can't just pick up an anatomy and physiology book and read it as though it were a novel. Unfortunately, confusion is likely without precise, specialized terminology. To prevent misunderstanding, anatomists use universally accepted terms to identify body structures precisely and with a minimum of words. As you study anatomy and physiology, you will be learning many new words. Knowing the derivation, or etymology terms are derived from Latin or Greek. For example, foramen is a Latin word for "hole," and magnum means "large." The foramen magnum is therefore a large hole in the skull through which the spinal cord attaches to the brain.

Prefixes and suffixes can be added to words to expand their meaning. For example, the suffix -itis means an inflammation, so appendicitis is an inflammation of the appendix. As new terms are introduced in this text, their meanings are often explained. I will present and explain the language of anatomy next.

Body Positions



Descriptions of anybody region or part require a common initial point of reference. Note that terms such as superior and inferior can be relative terms. For example, when a person is standing it would be accurate to say “the heart is superior to the stomach,” yet if that person were in a supine (lying down, face upward) position, this statement would seem not to be true. For accuracy and clarity, anatomists and physiologists describe these parts based on the premise that the body is in what is termed the anatomic position, which is then the point of common reference. An individual in the anatomic position stands upright with the feet parallel and flat on the floor, the upper limbs are at the sides of the body, and the palms face anteriorly (toward the front); the head is level, and the eyes look forward toward the observer. All of the anatomic and directional

1. A human standing erect with the face directed forward, the arms hanging to the sides, and the palms facing forward is in the anatomical position.
2. A person lying face upward is supine; a person lying face downward is prone.

Directional Terms

Directional terms always refer to the anatomical position, no matter what the actual position of the body.

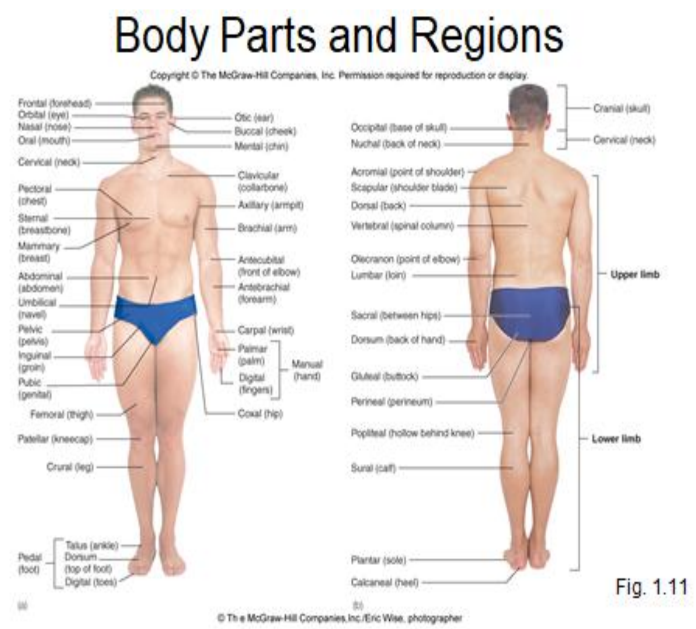
Right and left are retained as directional terms in anatomical terminology. Up is replaced by superior, down by inferior, front by anterior and back by posterior. In humans, superior is synonymous with **cephalic**, which means toward the head, because, when we are in the anatomical position, the head is the highest point. In humans, the term inferior is synonymous with **caudal**, which means toward the tail, which would be located at the end of the vertebral column if humans had tails. The terms cephalic and caudal can be used to describe directional movements on the trunk, but they are not used to describe directional movements on the limbs. The word **anterior** means “that which goes before,” and **ventral** means “belly.” The anterior surface of the human body is therefore the ventral surface, or belly, because the belly “goes first” when we are walking. The word **posterior** means “that which follows,” and **dorsal** means “back.” The posterior surface of the body is the dorsal surface, or back, which follows as we are walking. **Proximal** means “nearest,” whereas **distal** means “distant.” These terms are used to refer to linear structures, such as the limbs, in which one end is near another structure and the other end is farther away. Each limb is attached at its proximal end to the body, and the distal end, such as the hand, is farther away. **Medial** means “toward the midline,” and lateral means “away from the midline.” The nose is in a medial position in the face, and the eyes are lateral to the nose. **Superficial** describes a structure close to the surface of the body, and deep is toward the interior of the body. The skin is superficial to muscle and bone.

Body Parts and Regions

1. The body can be divided into a central region, consisting of the head, neck, and trunk, and the upper limbs and lower limbs. These divisions are useful for locating internal organs or describing the location of a pain or a tumor. The central region of the body consists of the head, neck, and trunk. The trunk can be divided into the thorax (chest), abdomen (region between the thorax and pelvis), and pelvis (the inferior end of the trunk associated with the hips). The upper limb is divided into the arm, forearm, wrist, and hand. The arm extends from the shoulder to the elbow, and the forearm extends from the elbow to the wrist. The lower limb is divided into the thigh, leg, ankle, and foot. The thigh extends from the hip to the knee, and the leg extends from the knee to the ankle. Note that, contrary to popular usage, the terms arm and leg refer to only a part of the respective limb.

2. Superficially, the abdomen can be divided into quadrants or into nine regions.

The abdomen is often subdivided superficially into quadrants by two imaginary lines—one horizontal and one vertical—that intersect at the navel. The quadrants formed are the right-upper, left-upper, right-lower, and left-lower quadrants. In addition to these quadrants, the abdomen is sometimes subdivided into regions by four imaginary lines: two horizontal and two vertical. These four lines create a "virtual" tic-tac-toe grid on the abdomen, resulting in nine regions: epigastric, right and left hypochondriac, umbilical, right and left lumbar, hypogastric, and right and left iliac. Health professionals use the quadrants and regions as reference points for locating underlying organs. For example, the appendix is in the right-lower quadrant, and the pain of an acute appendicitis is usually felt there.



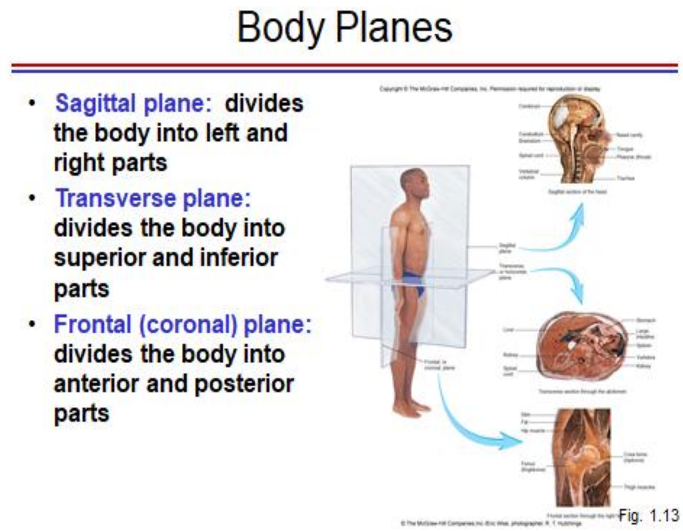
Planes
At times, it is useful to describe the body as having imaginary flat surfaces, called planes, passing through it. A plane divides, or sections, the body, making it possible to "look inside" and observe the body's structures.

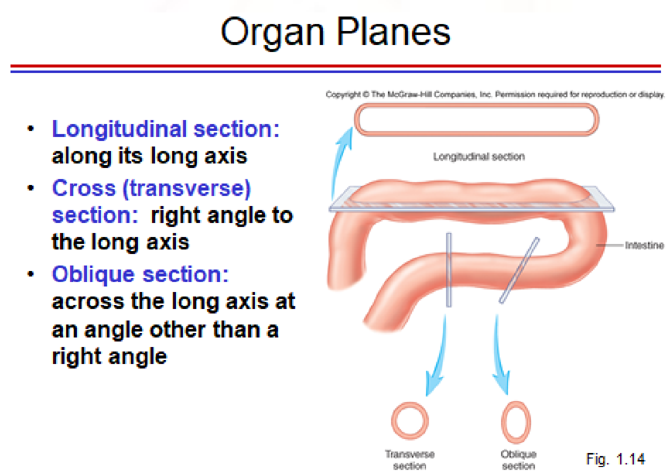
1. Planes of the body

- A sagittal plane divides the body into right and left parts. A median plane divides the body into equal right and left halves.
- A transverse (horizontal) plane divides the body into superior and inferior portions.
- A frontal (coronal) plane divides the body into anterior and posterior parts.

2. Sections of an organ
Organs are often sectioned to reveal their internal structure.

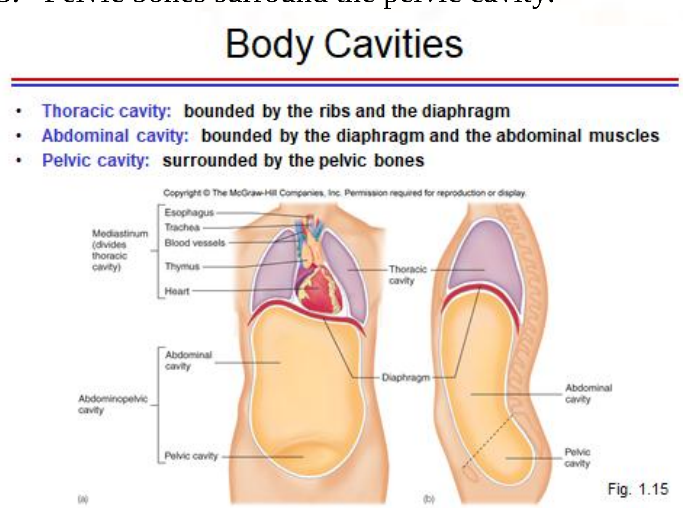
- A longitudinal section of an organ divides it along the long axis.
- A transverse (cross) section cuts at a right angle to the long axis of an organ.
- An oblique section cuts across the long axis of an organ at an angle other than a right angle.





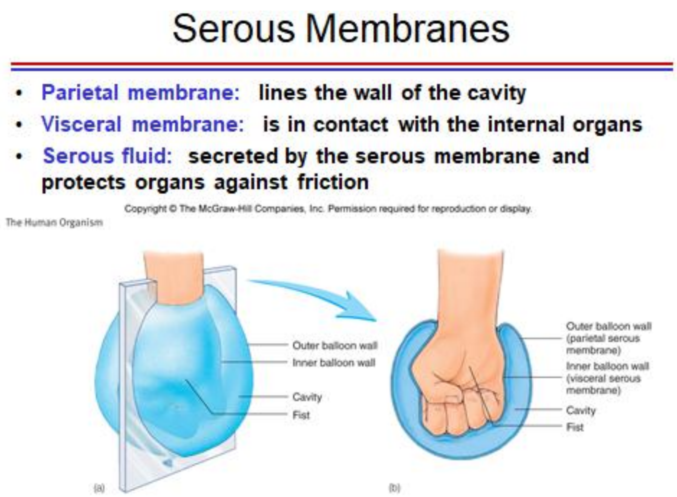
Body Cavities
Internal organs and organ systems are housed within enclosed spaces, or cavities. These body cavities are named according to either the bones that surround them or the organs they contain.

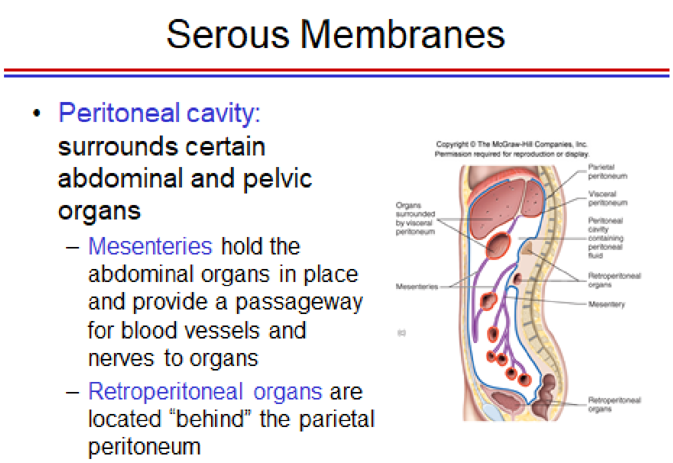
1. The mediastinum subdivides the thoracic cavity.
2. The diaphragm separates the thoracic and abdominal cavities.
3. Pelvic bones surround the pelvic cavity.

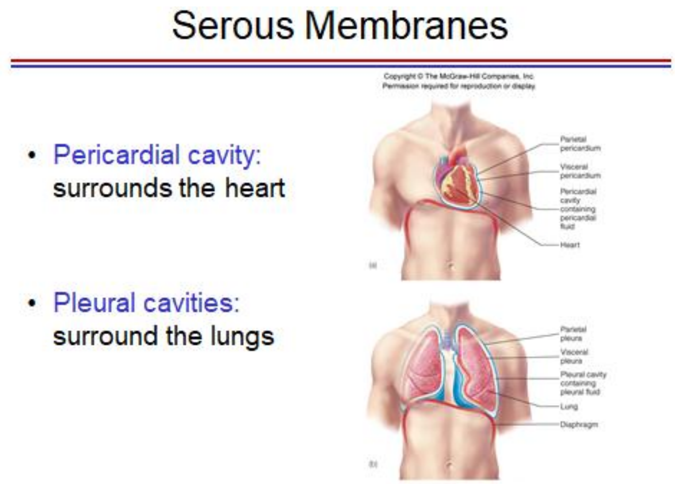


Serous Membranes

1. Serous membranes line the trunk cavities. The parietal portion of a serous membrane lines the wall of the cavity, and the visceral portion is in contact with the internal organs.
   - The serous membranes secrete fluid, which fills the space between the visceral and parietal membranes. The serous membranes protect organs from friction.
   - The pericardial cavity surrounds the heart, the pleural cavities surround the lungs, and the peritoneal cavity surrounds certain abdominal and pelvic organs.
2. Mesenteries are parts of the peritoneum that hold the abdominal organs in place and provide a passageway for blood vessels and nerves to the organs.
3. Retroperitoneal organs are located "behind" the parietal peritoneum.







Summary

You just embarked on an adventure into the amazing world of human anatomy and physiology. Both fields explore the incredible workings of the human body. Anatomy studies the form and structure of the body, whereas physiology examines how the body functions. In this module, you learned that structure and function are inseparable. Together, these applied sciences provide the basis for understanding health and human performance. I introduced you to a number of concepts in this module that will be used throughout the course and will prove central to your study of anatomy and physiology. The diverse topics in this module include: (1) a comparison of the disciplines of anatomy and physiology; (2) study tips for how to most effectively study for this course; (3) the body's levels of organization; (4) the basic vocabulary of anatomy and physiology that is derived from both Greek and Latin; (5) the core features of homeostasis, which is the general regulatory process for maintaining a healthy body; as well as (6) the general relationship between homeostasis, health, and disease.

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