

IN THIS CHAPTER

- » Placing anatomy and physiology in a scientific framework
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- » Looking at anatomy: planes, regions, and cavities
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Chapter 1

Anatomy and Physiology: The Big Picture

Human *anatomy* is the study of the human body's structures — all the parts that make up the physical body itself. *Physiology* is the study of how the human body works; how all the anatomical parts function together to keep an individual alive. Anatomy and physiology are bound together. As such, this book abandons the old technique of learning all the anatomy and then the physiology as though the two were independent. Here, we examine each body system, identify the structures within that system, and then discuss their functions.

Scientifically Speaking

Human anatomy and physiology are closely related to *biology*, which is the study of living things and their relationship with the rest of the universe, including all other living things. If you've studied biology, you understand the basics of how organisms operate. Anatomy and physiology narrow the science of biology by looking at the specifics of one species: *Homo sapiens*.



REMEMBER

Anatomy is form; physiology is function. You can't talk about one without talking about the other.

THE ANATOMY AND PHYSIOLOGY OF EVERYTHING ELSE

Scientifically speaking, human biology isn't more or less complex, specialized, or cosmically significant than the biology of any other species, and all are interdependent. Every species of animal, plant, and fungus on the planet has both anatomy and physiology. So does each species of *protist* (one-celled creatures, like amoebae) and bacteria. At the cellular level (see Chapter 3), all these groups are astoundingly similar. At the levels of tissues, organs, and organ systems, plants are very different from animals, and both plants and animals are equally dissimilar to fungi.

Each of these major groups, called a *kingdom*, has its own characteristic anatomy and physiology. It's evident at a glance to everyone at the beach that a starfish and a human are both animals, while the seaweed in the tide pool and the cedar tree on the shoreline are both plants. Obvious details of anatomy (the presence or absence of bright green tissue) and physiology (the presence or absence of movement) tell that story. The different forms within each kingdom have obvious differences as well: The cedar must stand on the shore, but the seaweed would die there. The starfish can move from one place to another within a limited range, while humans can (theoretically) go anywhere on the planet and survive there for at least a while. Scientists use these differences to classify organisms into smaller and smaller groups within the kingdom, until each organism is classified into its own special group.

Not that human anatomy and physiology aren't special. Humans' bipedal posture and style of locomotion are very special. There's nothing like a human hand anywhere except at the end of a human arm. Perhaps most special of all is the anatomy and physiology that allows (or maybe compels) humans to engage in science: our highly developed brain and nervous system. It's entirely within the norms of evolutionary theory that people would be most interested in their own species, so more humans find human anatomy and physiology more interesting than the anatomy and physiology of the tree. From here on, we're restricting our discussion to the anatomy and physiology of our own species.

How anatomy and physiology fit into science

Biologists base their work on the assumption that every structure and process, no matter how tiny in scope, must somehow contribute to the survival of the individual. So each process — and the chemistry and physics that drive it — must help keep the individual alive and meeting the relentless challenges of a continually changing environment. Although anatomy and physiology combined are classified as a subsection of biology, it's truly an interdisciplinary science.

Human *pathophysiology* is the study of “human anatomy and physiology gone wrong.” (The prefix *path-* is Greek for “suffering.”) It’s the interface of human biology and medical science. *Clinical medicine* is the application of medical science to alleviate an anatomical or physiological problem in an individual human.

Pathophysiology and clinical medicine aren’t the subject of this book, but we discuss applications of them when they’re particularly relevant to the physiology. You’re probably using this book to supplement instructional material in career training for a clinical environment, so the information throughout the book is slightly slanted in that direction. We chose the conditions that we briefly examine to demonstrate some characteristic of the system, especially its interaction with other systems, but we don’t discuss diagnosis or treatment.

TAXONOMY OF *HOMO SAPIENS*

Taxonomy is the science that seeks to classify and organize living things, expressed as a series of mutually exclusive categories. The highest (most inclusive) category is domain, of which there are three: Archea, Eubacteria, Eukaryota. Each of these domains is split into kingdoms, which are further divided until each individual organism is its own unique species. Outside of bacteria, all living things fall under the Eukaryota domain; the kingdoms are: Protista, Fungi, Plantae, and Animalia. Within each kingdom, the system classifies each organism into the hierarchical subgroups (and sometimes sub-subgroups) of phylum, class, order, family, genus, and species. Here’s the breakdown of humankind:

Kingdom Animalia: All animals.

Phylum Chordata: Animals that have a number of structures in common, particularly the *notochord*, a rodlike structure that forms the body’s supporting axis.

Subphylum Vertebrata: Animals with backbones.

Superclass Tetrapoda: Four-footed vertebrates.

Class Mammalia: Tetrapods with hair. Other classes of the vertebrata are Pisces (fish), Amphibia (frogs), Aves (birds), and Reptilia (scaly things).

Order Primates: Mammals with more highly developed brains, flexible hips and shoulders, and prehensile hands and feet (able to grasp).

Superfamily Hominoidea: Apes (chimpanzees, gorillas, orangutans, humans).

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Family Hominidae: Great apes, including humans.

Genus Homo: The human species is the only surviving species of our genus, though this genus included several species in the evolutionary past.

Species Sapiens: All species are given a two-part Latin name, in which the genus name comes first and a species epithet comes second. The biologists who name species sometimes try to use a descriptor in the epithet. For humans, they could have chosen “bipedal” or “talking” or “hairless,” but they chose “thinker.”

Variety Sapiens: Some species get a “varietal” name, usually indicating a difference that’s obvious but not necessarily important from an evolutionary point of view. The human species has one other variety, *Homo sapiens neanderthalensis*, which has been extinct for tens of thousands of years. All humans living since then are of one species variety, *Homo sapiens sapiens*. In the evolutionary classification of humans, there’s no biologically valid category below species variety.

Anatomy, gross and otherwise

Some biologists specialize in the anatomy and physiology of animals at various hierarchical levels (horses, fish, frogs) or particular organs (mammalian circulatory systems, olfaction in fish, insect hormones). Some focus solely on humans, others concentrate on other species, and still others examine the areas of overlap between humans and other animal species. These various areas of study contribute to our knowledge of biology in general and have important applications in clinical medicine. The work of anatomists contributes to medical advances, such as improved surgical techniques and the development of bioengineered prostheses.

Throughout this book, you encounter some information from each major subset of anatomy, including

- » **Gross anatomy:** The study of the large parts of an animal body — any animal body — that can be seen with the unaided eye. That’s the aspect of anatomy we concentrate on in this book.
- » **Histologic anatomy:** The study of different tissue types and the cells that comprise them. Histologic anatomists use a variety of microscopes to study the cells and tissues that make up the body.
- » **Developmental anatomy:** The study of the life cycle of the individual, from fertilized egg through adulthood, senescence (aging), and death. Body parts

change throughout the life span. For information about human developmental anatomy, see Chapter 15.

» **Comparative anatomy:** The study of the similarities and differences among the anatomical structures of different species, including extinct species. Information from comparative anatomy can help scientists understand the human body's structures and processes. For example, comparing the anatomy of apes to that of humans shows us what particular structures allow for our ability to walk upright on two legs.

A Little Chat about Jargon

Why does science have so many funny words? Why can't scientists just say what they mean, in plain English? Good question, with a two-part answer.

Creating better communication

Scientists need to be able to communicate with others in their field. They say what they mean (most of them, most of the time, to the best of their ability), but what they mean can't be said in the English language that people use to talk about routine daily matters.

Like people working in every field, scientists develop vocabularies of technical terminology and other forms of jargon so they can better communicate with other scientists. It's important that the scientist sending the information and the scientist receiving it both use the same words to refer to the same phenomenon. To understand anatomy and physiology, you must know and use the same terminology, too. The jargon can be overwhelming at first, but understanding the reason for it and taking the time to learn it before diving into the complicated content will make your learning experience less painful.

Establishing precise terminology

The second part of the answer starts with a little chat about jargon. Contrary to the belief of some, jargon is a good thing. *Jargon* is a set of words and phrases that people who know a lot about a particular subject use to talk together. There's jargon in every field (scientific or not), every workplace, every town, even every home. Families and close friends almost always use jargon in conversations with one another. Plumbers use jargon to communicate about plumbing. Anatomists and physiologists use jargon, much of which is shared with medicine and other fields of biology, especially human biology.

Scientists try to create terminology that's precise and easy to understand by developing it systematically. That is, they create new words by putting together existing and known elements. They use certain syllables or word fragments over and over to build new terms. With a little help from this book, you'll soon start to recognize some of these fragments. Then you can put the meanings of different fragments together and accurately guess the meaning of a term you've never seen before, just as you can understand a sentence you've never read before. Table 1-1 gets you started, listing some word fragments related to the organ systems we cover in this book.

TABLE 1-1 **Technical Anatomical Word Fragments**

Body System	Root or Word Fragment	Meaning
Skeletal system	os-, oste-; arth-	bone; joint
Muscular system	myo-, sarco-	muscle, striated muscle
Integument	derm-	skin
Nervous system	neur-	nerve
Endocrine system	aden-, estr-	gland, steroid
Cardiovascular system	card-, angi-, hema-, vaso-	heart (muscle), vessel, blood vessels
Respiratory system	pulmon-, bronch-	lung, windpipe
Digestive system	gastr-, enter-, dent-, hepat-	stomach, intestine, teeth, liver
Urinary system	ren-, neph-; ur-	kidney; urinary
Lymphatic system	lymph-, leuk-, -itis	lymph, white, inflammation
Reproductive system	andr-, uter-	male, uterine

But why do these terms have to be Latin and Greek syllables and word fragments? Why should you have to dissect and put back together a term like *iliohypogastric*? Well, the terms that people use in common speech are understood slightly differently by different people, and the meanings are always undergoing change. Not so long ago, for example, no one speaking plain English used the term *laptop* to refer to a computer or *hybrid* to talk about a car. It's possible that, not many years from now, almost no one will understand what people mean by those words. Scientists, however, require consistency and preciseness to describe the things they talk about in a scientific context. The relative vagueness and changeability of terms in plain English makes this impossible. In contrast, Greek and Latin stopped changing centuries ago: *ilio*, *hypo*, and *gastro* have the same meaning now as they did 200 years ago.



TIP

Every time you come across an anatomical or physiological term that's new to you, see if you recognize any parts of it. Using this knowledge, go as far as you can in guessing the meaning of the whole term. After studying Table 1-1 and the other vocabulary lists in this chapter, you should be able to make some pretty good guesses.

Looking at the Body from the Proper Perspective

Remember that story about a friend of a friend that went in to have a foot amputated only to awaken from surgery to find they removed the wrong one? This story highlights the need for a consistent perspective to go with the jargon. Terms that indicate direction make no sense if you're looking at the body the wrong way. You likely know your right from your left, but ignoring perspective can get you all mixed up. This section shows you the anatomical position, planes, regions, and cavities, as well as the main membranes that line the body and divide it into major sections.

Getting in position

Stop reading for a minute and do the following: Stand up straight. Look forward. Let your arms hang down at your sides and turn your palms so they're facing forward. You are now in *anatomical position* (see Figure 1-1). Unless you are told otherwise, any reference to location (diagram or description) assumes this position. Using anatomical position as the standard removes confusion.

The following list of common anatomical descriptive terms (direction words) that appear throughout this and every other anatomy book may come in handy:

- » **Right:** Toward the patient's right
- » **Left:** Toward the patient's left
- » **Anterior/ventral:** Front, or toward the front of the body
- » **Posterior/dorsal:** Back, or toward the back of the body
- » **Medial:** Toward the middle of the body
- » **Lateral:** On the side or toward the side of the body
- » **Proximal:** Nearer to the point of attachment or the trunk of the body

- » **Distal:** Farther from the point of attachment or the trunk of the body (think "distance")
- » **Superficial:** Nearer to the surface of the body
- » **Deep:** Farther from the surface of the body
- » **Superior:** Above or higher than another part
- » **Inferior:** Below or lower than another part

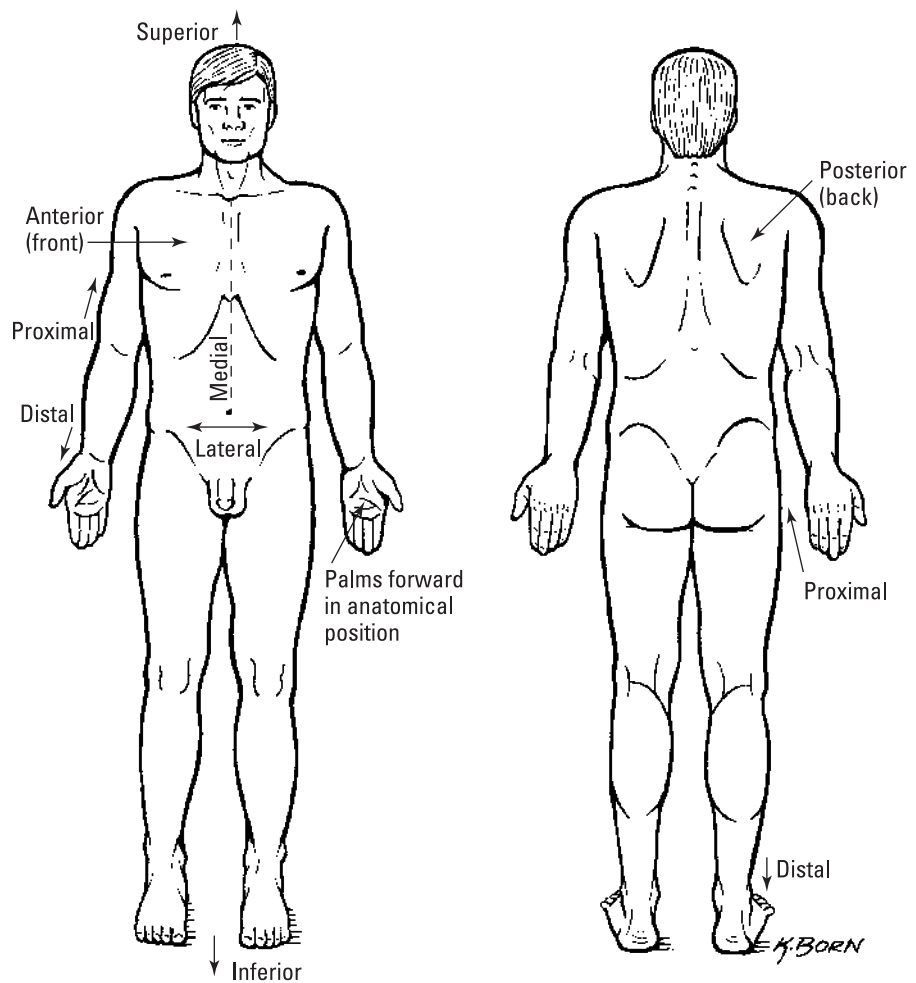


FIGURE 1-1:
The standard
anatomical
position.

Illustration by Kathryn Born, MA



Notice that this list of terms is actually a series of pairs. Learning them as pairs is more effective and useful.

TIP

Dividing the anatomy

If you've taken geometry, you know that a *plane* is a flat surface and that a straight line can run between two points on that flat surface. Geometric planes can be positioned at any angle. In anatomy, generally three planes are used to separate the body into sections. Figure 1-2 shows you what each plane looks like. The reason for separating the body with imaginary lines — or making actual *cuts* referred to as *sections* — is so that you know which *half* or *portion* of the body or organ is being discussed. When identifying or comparing structures, you need to know your frame of reference. The anatomical planes are as follows:

- » **Frontal plane:** Divides the body or organ into anterior and posterior portions — think front and back.
- » **Sagittal plane:** Divides the body or organ lengthwise into right and left sections. If the vertical plane runs exactly down the middle of the body, it's referred to as the *midsagittal plane*.
- » **Transverse plane:** Divides the body or organ horizontally, into superior and inferior portions — think top and bottom. Diagrams from this perspective can be quite disorienting. You can think of the body like a music box that has a top that opens on a hinge. The transverse plane is where the music box top separates from the bottom of the box. Imagine that you open the box by lifting the lid and are looking down at the contents.



REMEMBER

Anatomical planes do not always create two equal portions and can “pass through” the body at any angle. The three planes provide an important reference but don't expect the structures of the body, and especially the joints, to line up or move along the standard planes and axes.

Mapping out your regions

The anatomical planes orient you to the human body, but *regions* (shown in Figure 1-3) compartmentalize it. Just like on a map, a region refers to a certain area. The body is divided into two major portions: axial and appendicular. The *axial body* runs right down the center (axis) and consists of everything except the limbs, meaning the head, neck, thorax (chest and back), abdomen, and pelvis. The *appendicular body* consists of appendages, otherwise known as *upper and lower extremities* (which you call arms and legs).

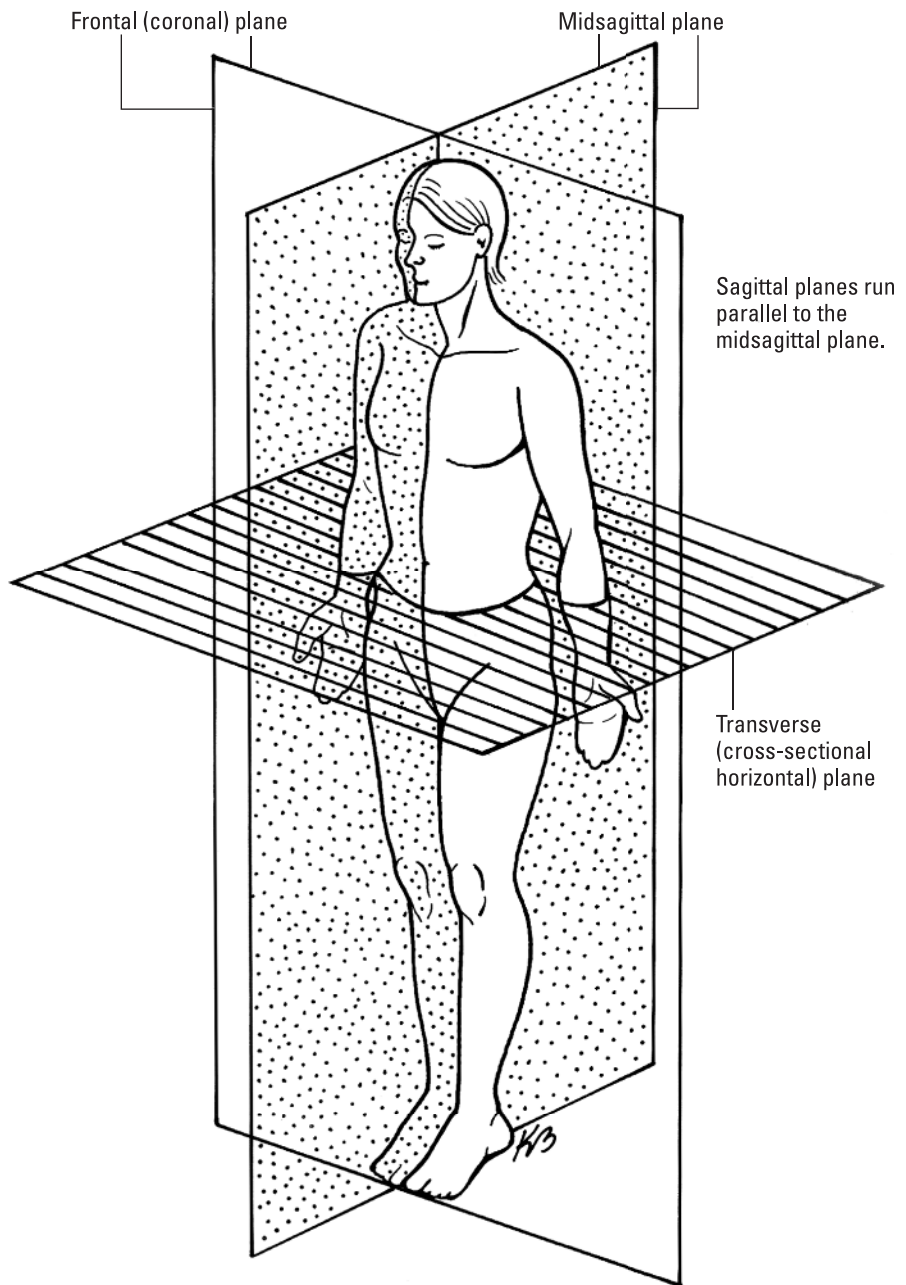


FIGURE 1-2:
Planes of the
body: frontal,
sagittal, and
transverse.

Illustration by Kathryn Born, MA

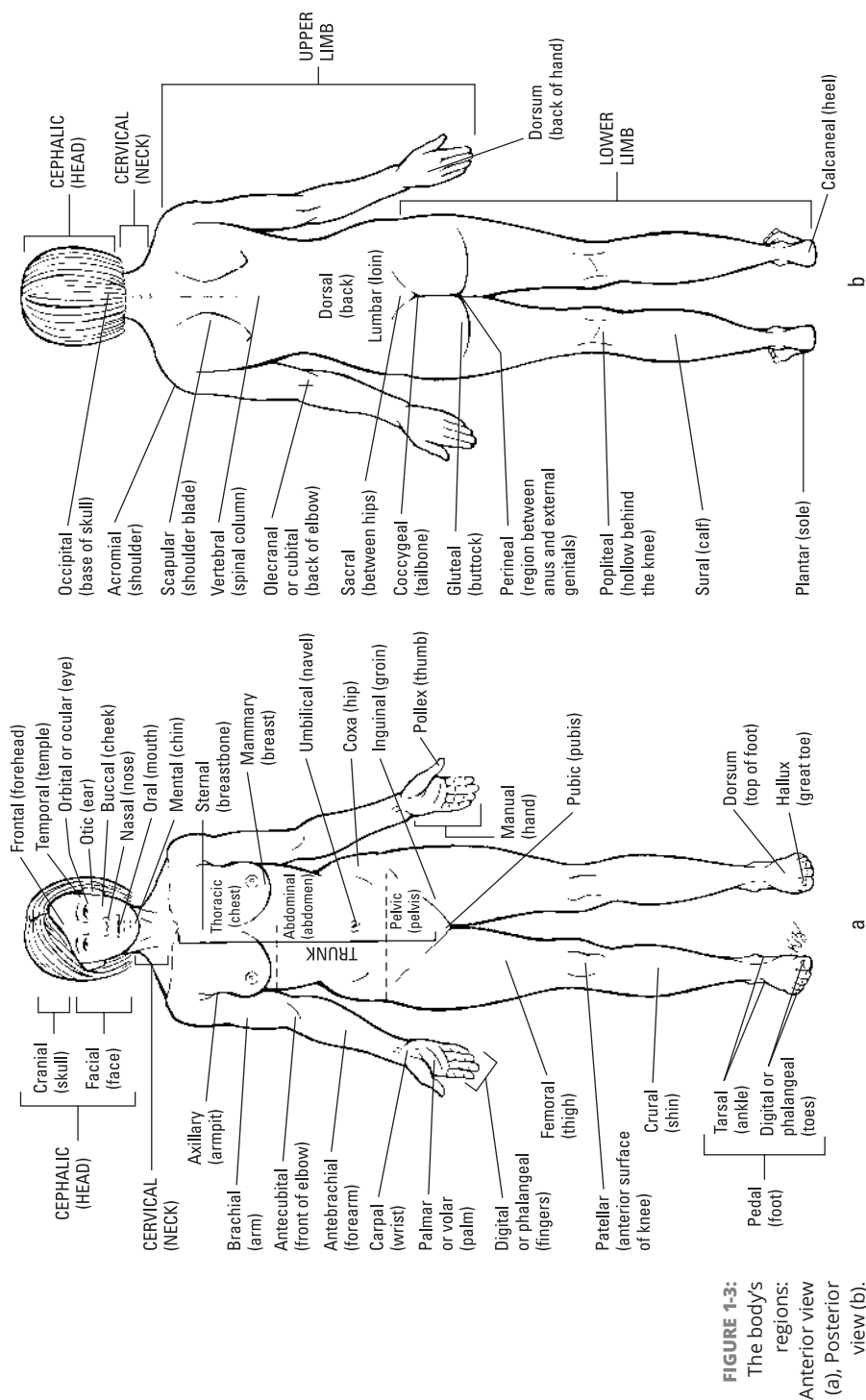


Illustration by Kathryn Born, MA

FIGURE 1-3:
The body's
regions:
Anterior view
(a), Posterior
view (b).

Here's a list of the axial body's main regions:

» **Head and neck**

- Cephalic (head)
- Cervical (neck)
- Cranial (skull)
- Frontal (forehead)
- Nasal (nose)
- Occipital (base of skull)
- Oral (mouth)
- Orbital/ocular (eyes)

» **Thorax**

- Axillary (armpit)
- Costal (ribs)
- Deltoid (shoulder)
- Mammary (breast)
- Pectoral (chest)
- Scapular (shoulder blade)
- Sternal (breastbone)
- Vertebral (backbone)

» **Abdomen**

- Abdominal (abdomen)
- Gluteal (buttocks)
- Inguinal (bend of hip)
- Lumbar (lower back)
- Pelvic (area between hipbones)
- Perineal (area between anus and external genitalia)
- Pubic (genitals)
- Sacral (end of vertebral column)

Here's a list of the appendicular body's main regions:

» **Upper extremity**

- Antebrachial (forearm)
- Antecubital (inner elbow)
- Brachial (upper arm)
- Carpal (wrist)
- Cubital (elbow)
- Digital (fingers/toes)
- Manual (hand)
- Palmar (palm)

» **Lower extremity**

- Crural (shin, front of lower leg)
- Femoral (thigh)
- Patellar (front of knee)
- Pedal (foot)
- Plantar (arch of foot)
- Popliteal (back of knee)
- Sural (calf, back of lower leg)
- Tarsal (ankle)

Casing your cavities

If you remove all the internal organs, the body is empty except for the bones and other tissues that form the space where the organs were. Just as a dental cavity is a hole in a tooth, the body's cavities are "holes" where organs are held (see Figure 1-4). The two main cavities are the *dorsal cavity* and the *ventral cavity*.

The dorsal cavity consists of two cavities that contain the central nervous system. The first is the *cranial cavity*, the space within the skull that holds your brain. The second is the *spinal cavity* (or *vertebral cavity*), the space within the vertebrae where the spinal cord runs through your body.

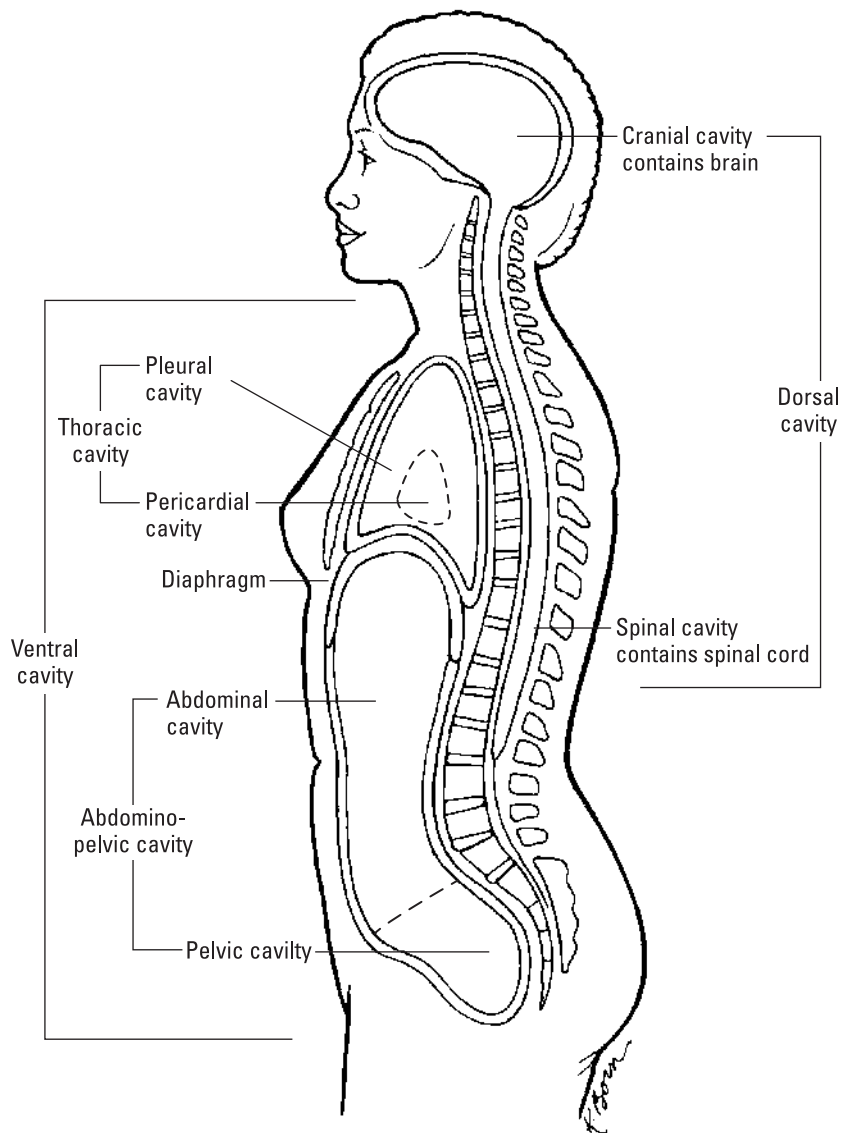


FIGURE 1-4:
The body's
cavities.

Illustration by Kathryn Born, MA

The ventral cavity is much larger and contains all the organs not contained in the dorsal cavity. The ventral cavity is divided by the diaphragm into smaller cavities: the *thoracic cavity*, which contains the heart and lungs, and the *abdominopelvic cavity*, which contains the organs of the abdomen and the pelvis. The thoracic cavity is divided into the right and left *pleural cavities* (lungs) and the *pericardial cavity*

(heart). The abdominopelvic cavity is also subdivided. The *abdominal cavity* contains organs such as the stomach, liver, spleen, and most of the intestines. The *pelvic cavity* contains the reproductive organs, the bladder, the rectum, and the lower portion of the intestines.

Additionally, the abdomen is divided into quadrants and regions. The mid-sagittal plane and a transverse plane intersect at an imaginary axis passing through the body at the *umbilicus* (navel or belly button). This axis divides the abdomen into *quadrants* (four sections). Putting an imaginary cross on the abdomen creates the right upper quadrant, left upper quadrant, right lower quadrant, and left lower quadrant. Physicians take note of these areas when a patient describes symptoms of abdominal pain.

The regions of the abdominopelvic cavity include the following:

- » **Epigastric:** The central part of the abdomen, just above the navel
- » **Hypochondriac:** Doesn't moan about every little ache and illness but lies to the right and left of the epigastric region and just below the cartilage of the rib cage (*chondral* means "cartilage," and *hypo-* means "below")
- » **Umbilical:** The area around the umbilicus
- » **Lumbar:** Forms the region of the lower back to the right and left of the umbilical region
- » **Hypogastric:** Below the stomach and in the central part of the abdomen, just below the navel
- » **Iliac:** Lies to the right and left of the hypogastric regions near the hipbones

Organizing Yourself on Many Levels

Anatomy and physiology are concerned with the level of the individual body, what scientists call the *organism*. However, you can't merely focus on the whole and ignore the role of the parts. The life processes of the organism are built and maintained at several physical levels, which biologists call *levels of organization*: the cellular level, the tissue level, the organ level, the organ system level, and the organism level (see Figure 1-5). In this section, we review these levels, starting at the bottom.

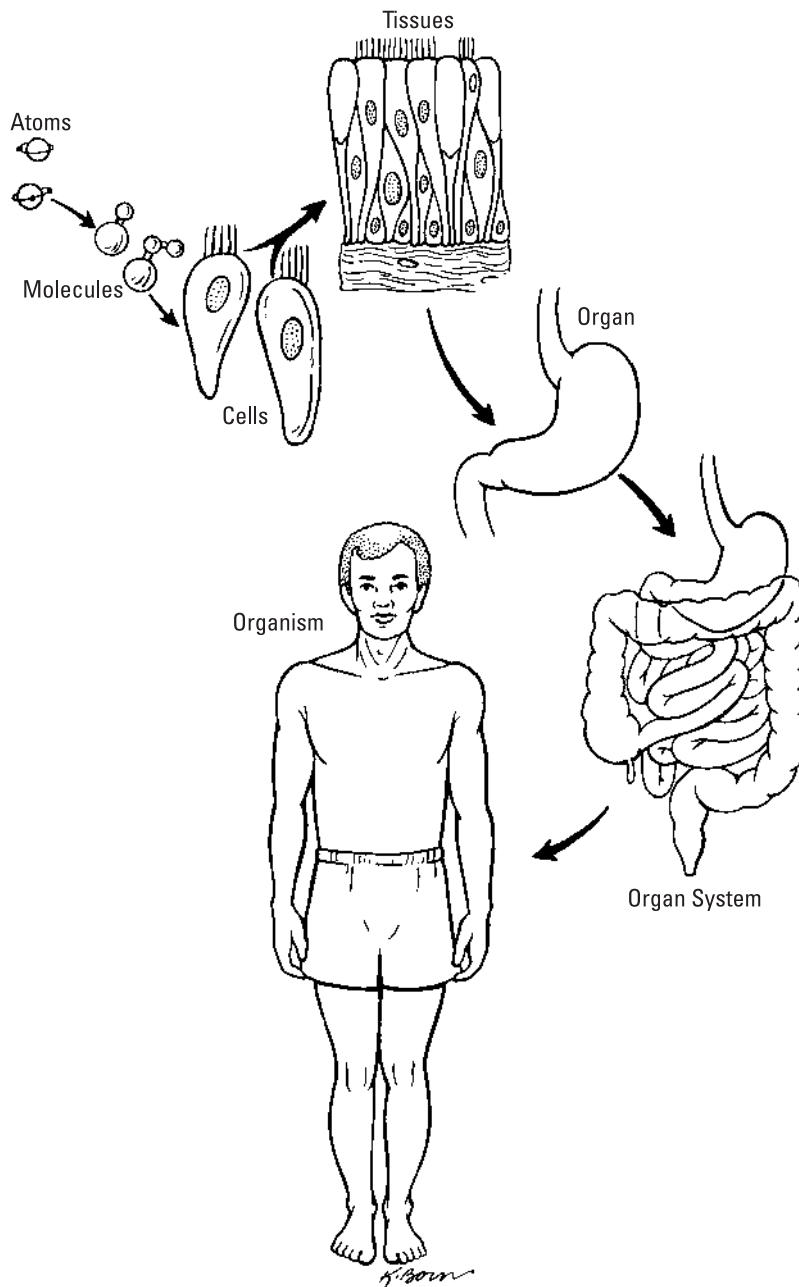


FIGURE 1-5:
Levels of
organization in
the human body.

Illustration by Kathryn Born, MA

Level I: The cellular level

If you examine a sample of any human tissue under a microscope, you see cells, possibly millions of them. All living things are made of cells. In fact, “having a cellular level of organization” is inherent in any definition of “organism.” The work of the body actually occurs in the cells; for example, your whole heart beats to push blood around your body because of what happens inside the cells that create its walls.

Level II: The tissue level

A *tissue* is a structure made of many cells — usually several different kinds of cells — that performs a specific function. Tissues are divided into four categories:

- » **Connective tissue** serves to support body parts and bind them together. Tissues as different as bone and blood are classified as connective tissue.
- » **Epithelial tissue (epithelium)** functions to line and cover organs as well as carry out absorption and secretion. The outer layer of the skin is made up of epithelial tissue.
- » **Muscle tissue** — surprise! — is found in the muscles, which allow your body parts to move; in the walls of hollow organs (such as intestines and blood vessels) to help move their contents along; and in the heart to move blood along via the acts of contraction and relaxation. (Find out more about muscles in Chapter 6.)
- » **Nervous tissue** transmits impulses and forms nerves. Brain tissue is nervous tissue. (We talk about the nervous system in Chapter 7.)

Level III: The organ level

An *organ* is a group of tissues assembled to perform a specialized physiological function. For example, the stomach is an organ that has the specific physiological function of breaking down food. By definition, an organ is made up of at least two different tissue types; many organs contain tissues of all four types. Although we can name and describe all four tissue types that make up all organs, as we do in the preceding section, listing all the organs in the body wouldn’t be so easy.

Level IV: The organ system level

Human anatomists and physiologists have divided the human body into *organ systems*, groups of organs that work together to meet a major physiological need.

For example, the digestive system is one of the organ systems responsible for obtaining energy from the environment. Realize, though, that this is not a classification system for your organs. The organs that “belong” to one system can have functions integral to another system. The pancreas, for example, produces enzymes vital to the breakdown of our food (digestion), as well as hormones for the maintenance of our homeostasis (endocrine).

The chapter structure of this book is based on the definition of organ systems.

Level V: The organism level

The whole enchilada. The real “you.” As we study organ systems, organs, tissues, and cells, we’re always looking at how they support you on the organism level.

TAKING PICTURES OF YOUR INSIDES

For early anatomists like Hippocrates and da Vinci, the images they had were the sketches they made for themselves. The drawings made by Andreas Vesalius were compiled into the first anatomical atlas and the accuracy, considering it was the 16th century, is impressive. However, it is a German physicist named Wilhelm Conrad Roentgen who’s remembered as “the father of medical imaging.” In 1895, Roentgen changed the game by recording the first image of the internal parts of a living human: an X-ray image of his wife’s hand. By 1900, X-rays were in widespread use for the early detection of tuberculosis, at that time a common cause of death. *X-rays* are beams of radiation emitted from a machine toward the patient’s body, and X-ray images show details only of hard tissues, like bone, that reflect the radiation. In this way, they’re similar to photographs. Refinements and enhancements of X-ray techniques were developed all through the 20th century, with extensive use and major advances during World War II. The X-ray is still a widely used method for medical diagnosis, not just for bone breaks but for screening for signs of disease, especially tumors.

In the 1970s, computer technology took off, taking medical imaging technology with it. Digital imaging techniques began to be applied to convert multiple flat-slice images into one three-dimensional image. The first technology of this sort was called *computed axial tomography* (commonly called a CAT or CT scan). The technique combines multiple X-ray images of varying depths into images of whole structures inside the body. Contrast dye can be used to highlight particular areas, which is especially useful for a quick assessment (for example, after a trauma).

Another class of imaging technology utilizing radiation is positron emission tomography (PET). A radioactive isotope can be attached to a specific molecule — a drug, for

example. After administering the drug to the patient, the isotope emits radiation, which can be traced and followed with radiation detectors. This is especially useful for testing the efficacy of drugs in a clinical research setting. It's unique in that the scan provides information of organ function on a cellular level.

Ultrasound imaging technology uses the echoes of sound waves sent into the body to generate a signal that a computer turns into a real-time image of anatomy and physiology. Ultrasound can also produce audible sounds, so the anatomist or physiologist can, for example, watch the pulsations of an artery while hearing the sound of the blood flowing through it. Although all these technologies are considered noninvasive, ultrasound is the least invasive of all (no radiation) so it's used more freely, especially in sensitive situations like pregnancy.

Magnetic resonance imaging (MRI) utilizes magnetic fields and radio pulses to create an image of the interior. Soft tissue structures are more difficult to scan using other methods, especially those found underneath bone. The resulting 3D image can pinpoint anomalies within an organ, often in great detail. Since the early 1990s, neuroscientists have been using a type of specialized MRI scan, called *functional MRI* (fMRI), to acquire images of the brain. Images can be recorded over time, and the active areas of the brain "light up" on the scan, showing which parts are active during specific tasks. Basically, fMRI enables scientists to watch a patient's or research subject's thoughts as he or she is thinking them!

Digital imaging technologies produce images that are extremely clear and detailed. The images can be produced much more quickly and cheaply than older technologies allowed for, and the images can be easily duplicated, transmitted, and stored. The amount of anatomical and physiological knowledge that digital imaging technologies have helped generate over the past 30 years has transformed biological and medical science. As the techniques are continually researched and developed, our understanding of physiology and accuracy in diagnostics will continue to improve.

