Chapter 1

Anatomy and Physiology: The Big Picture

In This Chapter

- Placing anatomy and physiology in a scientific framework
- Jawing about jargon
- Looking at anatomy: planes, regions, and cavities
- Delineating life's levels of organization

Human *anatomy* is the science of the human body's structures — things that can be touched, weighed, and analyzed. In this book, we glance at hundreds of structures: tissues, organs, organ systems, and points of contact between organ systems. We take a slightly closer look at a few specific tissues and organs. We also cover human *physiology,* which is the chemistry and physics of these structures and how they all work together to support the processes of life in each individual.

Scientifically Speaking

Human anatomy and physiology are closely related to *biology,* which is the science of living beings and their relationship with the rest of the universe, including all other living beings. 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 the plasmodia that cause malaria). At the cellular level (see Chapter 3), all these groups are astoundingly similar. At the levels of tissues, organs, and organ systems (the provenance of anatomy and physiology), 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 alga 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 locomotion) tell that story. The different forms within each kingdom have obvious differences as well: The cedar must stand on the shore but the alga 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, with the appropriate accoutrements of culture (a human adaptation), survive there for at least a while. (That is, assuming the cedar and the alga keep on photosynthesizing.) Scientists use these differences to classify organisms into smaller and smaller groups within the kingdom, until each organism is classified into its own "specie-al" group.

Not that human anatomy and physiology aren't "specie-al." Humans' bipedal posture and style of locomotion are very specie-al. There's nothing like a human hand anywhere but at the end of a human arm. Most specie-al of all, possibly, is the anatomy and physiology that allows (or maybe compels) humans to engage in science: humankind's highly developed brain and nervous system. It's entirely within the norms of evolutionary theory that people would be most interested in their own specie-alties, so more humans find human anatomy and physiology more interesting than the anatomy and physiology of the alga. 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 take for granted that human anatomy and physiology evolved from the anatomy and physiology of ancient forms. These scientists 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 structures within which the chemistry and physics of the process actually happen — must help keep the individual alive and meeting the relentless challenges of a continually changing environment. Evolution favors processes that work.

Human *pathophysiology* is the science 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.

Clinical medicine isn't the subject of this book. Many of the chapters do contain pathophysiology sections, but those sections have no relevant information on patient care. We chose the conditions that we briefly sketch in those sections to demonstrate some characteristic of the system under discussion, especially its interaction with other systems. However, we're guessing that a large proportion of readers are 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.

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 human knowledge of biology in general and of clinical medicine in particular. 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 these 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. This subject is closely related to evolutionary biology. Information from comparative anatomy can help scientists understand the human body's structures and processes. For example, the comparative anatomy of humans and living and extinct apes can elucidate the structures in the human limbs that enable the bipedal posture.

Taxonomy of *Homo sapiens*

Taxonomy is the science of evolutionary relationships, expressed as a series of mutually exclusive categories. The highest (most inclusive) category is *kingdom,* of which there are five: Monera, 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: Apes and monkeys.

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

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.

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 short and long answers.

Creating better communication

The short answer is, scientists do 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. Scientists develop vocabularies of technical terminology and other forms of jargon so they can communicate better with other scientists. It's important that the scientist sending the information and the scientist receiving the information both use the same words to refer to the same phenomenon. To communicate in science, you must know and use the same terminology, too.

Establishing precise terminology

The longer answer to the question of why scientists don't say what they mean 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 and technical terminology, 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

(continued)

Table 1-1 *(continued)*

Circulatory system	card- angi- hema- arter- ven- erythro-	heart (muscle) vessel blood artery venous red
Respiratory system	pulmon- bronch-	lung windpipe
Digestive system	gastr- enter- dent- hepat-	stomach intestine teeth liver
Urinary system	ren- neph- ur-	kidney kidney urinary
Immune system	lymph- leuk- -itis	lymph white inflammation
Reproductive system	vagin- uter-	vagina uterine

But why do these terms have to be Latin and Greek syllables and word fragments? Why should you have to parse and put back together a term like *iliohypogastric?* One reason is the contrast between the preciseness with which scientists must name and describe the things they talk about in a scientific context and the relative vagueness and changeability of terms in plain English. 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. In contrast, scientific Greek and Latin stopped changing centuries ago: *ilio, hypo,* and *gastro* have the same meaning now as they did 200 years ago.

Problems can come up when the specialists who use the jargon want to communicate with someone outside their field. The specialists must translate their message into more common terms to communicate it. Problems can also come up when someone approaching a field, such as a student, fails to make progress understanding and speaking the field's jargon. This book aims to help you make the necessary progress.

TIP

Every time you come across an anatomical or physiological term that's new to you, pull it apart to see whether any of its fragments are familiar. 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

We want to make sure that you know where we're coming from when we use certain terms. If you don't look at the body from the correct perspective, you'll have your right and left confused. 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. Stand up straight. Look forward. Let your arms hang down at your sides with your palms facing forward. You are now in *anatomical position* (see Figure 1-1). Whenever you see an anatomical drawing, the body is in this position. Using this position as the standard removes confusion.

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

- **Anterior:** Front or toward the front of the body
- **Ventral:** Front or toward the front of the body
- **Posterior:** Back or toward the back of the body
- **Dorsal:** Back or toward the back of the body
- **Caudal:** Near or toward the tail
- **Prone:** Lying on the stomach, face down
- **Supine:** Lying on the back, face up
- **Lateral:** On the side or toward the side of the body
- **Medial or median:** In the middle or toward the middle 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
- **Central:** Near the center (median) of the body or middle of an organ
- **Peripheral:** Away from the center (midline) of the body or an organ

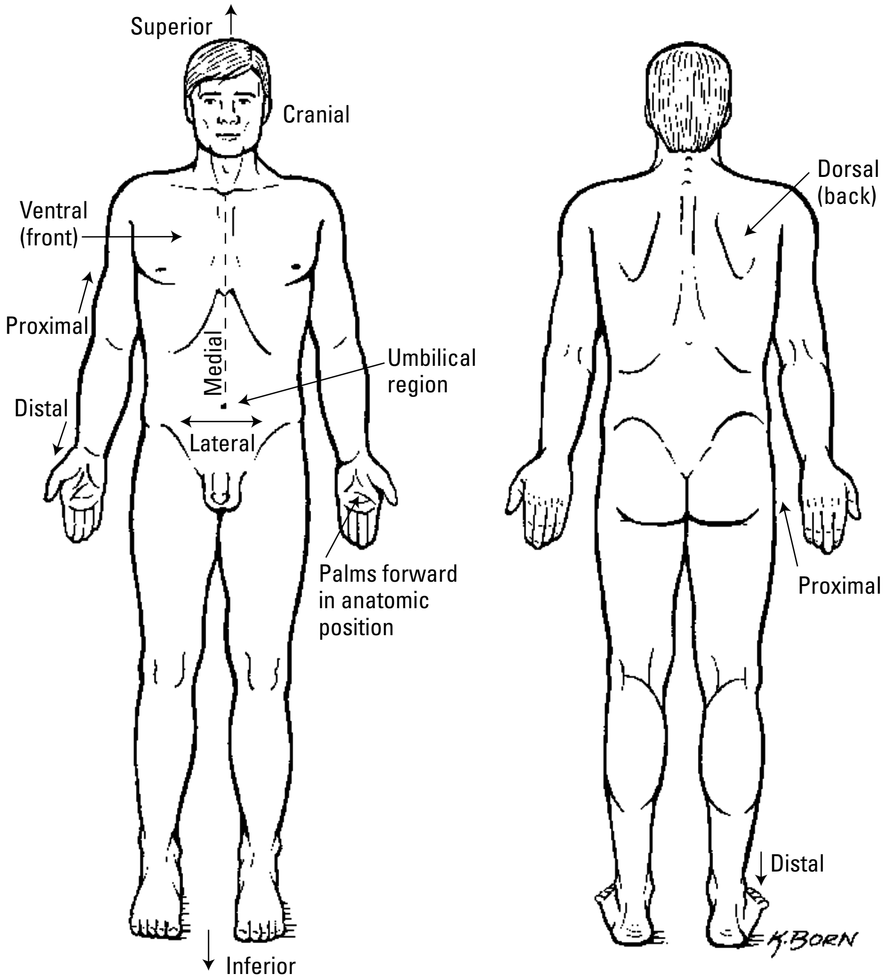

Figure 1-1: The standard anatomical position.

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, usually three planes 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 by making actual *cuts* referred to as *sections* — is so that you know which *half* or *portion* of the body or organ is being discussed. The anatomical planes are as follows:

- **Frontal plane:** Divides the body or organ into a front (anterior) portion and a rear (posterior) portion.
- **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.* Otherwise, a sagittal plane can run vertically down through the body at any point, creating a *longitudinal section.*
- **Transverse plane:** Divides the body or organ horizontally, into top (superior) and bottom (inferior) portions. Dividing horizontally doesn't necessarily yield two equal divisions; that is, a transverse plane doesn't always go through the waist area to separate the body into top and bottom. Transverse planes can go anywhere to create *cross sections.* When looking at a cross section of a body part, imagine that the body is sectioned horizontally. Or think of 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 you look at the material lining the lid. That's the vantage point that you have when looking at a cross section.

REMEMBER

Anatomical planes can "pass through" the body at any angle. The planes are arbitrary for the convenience of anatomists. 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

Three types of planes divide the human body, but *regions* compartmentalize the body's surface. 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.*

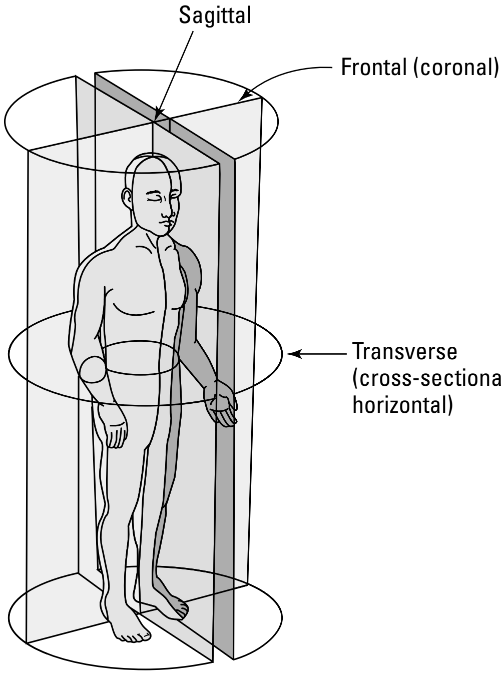

Figure 1-2: Planes of the body: Frontal, sagittal, and transverse.

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Taking pictures of your insides

For anatomists and physiologists from Aristotle to Charles Darwin, the images they had were the sketches they made for themselves. Some of them were pretty good at it: Darwin's sketches of beaks of the finches of the Galapagos Islands were both beautiful and scientifically valuable.

Darwin made scientific history in his own way, of course, but it was a German physicist named Wilhelm Conrad Roentgen who's remembered as "the father of medical imaging." In 1895, Roentgen recorded 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 screening for signs of disease, usually 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), in which multiple X-ray images are combined into cross-sectional pictures of structures inside the body. These detailed and extensive images were unlike anything that had been available to anatomists before. CT technology is still an active area of development. Major technology manufacturers maintain robust product lines of CT instruments and accoutrements for use in clinics and clinical research.

Another class of imaging technologies uses radiation from within the body to create the images that show bodily processes — physiology as well as anatomy. A substance called a *radiopharmaceutical,* which combines a radioactive isotope and a drug, is administered to the patient. It travels to and concentrates in the anatomical structure of interest, and the drug is metabolized there. The isotope emits radiation continuously from within the body, allowing the metabolism of the drug to be traced by radiation detectors and digitally converted to images. One of these *nuclear medicine* techniques, called *positron emission tomography* (PET), can show precisely how some cells use sugar. Nuclear medicine techniques have been in use since the 1950s and, like other imaging technologies, continue to be developed and applied clinically and in research.

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, and so is used more freely, especially in sensitive situations like pregnancy.

Since the early 1990s, neuroscientists have been using a type of specialized *magnetic resonance imaging* (MRI) scan, called *functional MRI* (fMRI), to acquire images of the brain. Functional imaging enables scientists to watch a patient's or research subject's thoughts as he or she is thinking them! This aspect of medical imaging has profound implications.

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.

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

- **Head and neck**
  - Cephalic (head)
  - Cervical (neck)
  - Cranial (skull)
  - Frontal (forehead)
  - Nasal (nose)
  - Occipital (back of head)
  - Ophthalmic (orbital, eyes)
  - Oral (mouth)

- **Thorax**
  - Axillary (armpit)
  - Costal (ribs)
  - Mammary (breast)
  - Pectoral (chest)
  - Sternal (breastbone)
  - Vertebral (backbone)
- **Abdomen**
  - Celiac (abdomen)
  - Gluteal (buttocks)
  - Groin (area of pelvis near thigh)
  - Inguinal (bend of hip)
  - Lumbar (lower back)
  - Pelvic (area between hipbones)
  - Perineal (area between anus and external genitalia)
  - Sacral (end of vertebral column)

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

- **Upper extremity**
  - Antebrachial (forearm)
  - Brachial (arm)
  - Carpal (wrist)
  - Cubital (elbow)
  - Palmar (palm)
- **Lower extremity**
  - Crural (leg, from knee to ankle)
  - Femoral (thigh)
  - Patellar (front of knee)
  - Pedal (foot)
  - Popliteal (back of knee)
  - Tarsal (ankle)

Casing your cavities

If you remove all the internal organs, the body is empty except for the bones and 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 1-3). The two main cavities are the *dorsal cavity* and the *ventral cavity*.

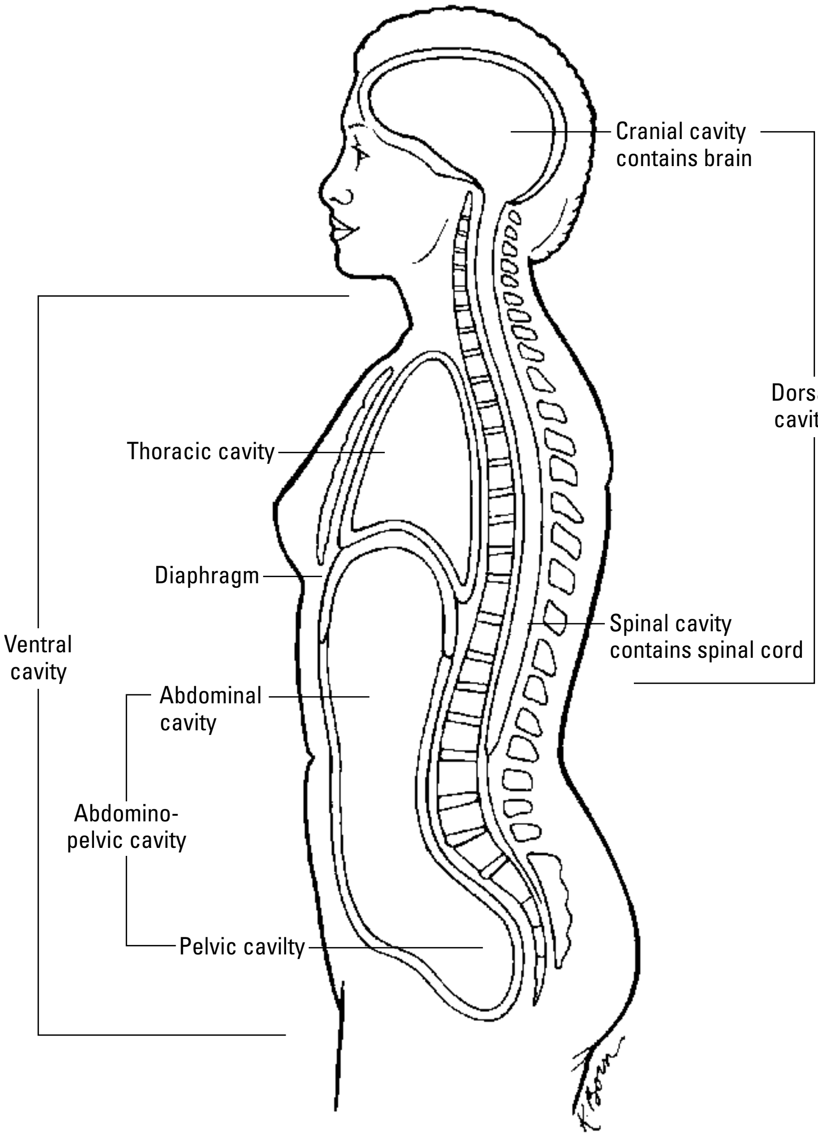

Figure 1-3: The body's cavities.

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,* the space within the vertebrae where the spinal cord runs through your body.

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 *abdomino pelvic cavity,* which contains the organs of the abdomen and the pelvis. The abdominal organs are the stomach, liver, gallbladder, 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 navel (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:** Above the stomach and in 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")
- **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
- **Umbilical:** The area around the navel (the umbilicus)
- **Lumbar:** Forms the region of the lower back to the right and left of the umbilical region

Organizing Yourself on Many Levels

Anatomy and physiology focus on the level of the individual body, what scientists call the *organism.* 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 1-4). In this section, we review these levels, starting at the bottom.

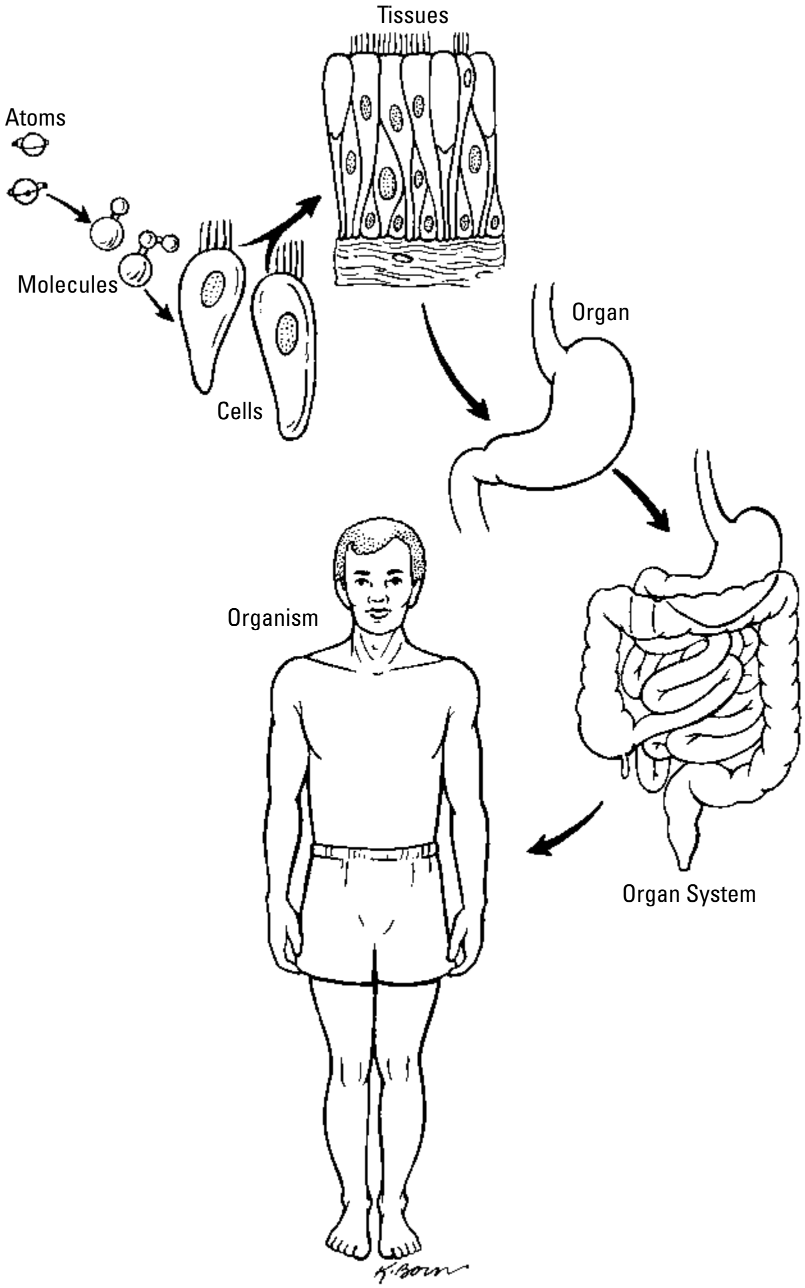

Figure 1-4: Levels of organization in the human body.

Level I: The cellular level

If you examine a sample of any human tissue under a microscope, you see cells, possibly millions of cells. All living things are made of cells. In fact, "having a cellular level of organization" is inherent in any definition of "organism." We discuss the cellular level of organization in some detail in Chapter 3.

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 classes:

- **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)** lines the inside of organs within the body and covers the body. 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 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 5.)
- **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 part of the body that performs 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.

The organs that "belong" to one system can have functions integral to another system. In fact, most organs contribute to more than one system. The blood vessels are an excellent example: They serve as a transportation network, delivering nutrients produced by the digestive system to the skeletal muscles to provide energy for locomotion and to the uterus to support the developing fetus. They remove the byproducts of the energy consumed in locomotion and by the fetus in development and carry them to the organs of the urinary system for excretion.

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. Other organ systems include the musculoskeletal system, the integument, the nervous system, and on down the list. 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 from the organism level.