PRINCIPLES OF ANATOMY & PHYSIOLOGY

1ST ASIA–PACIFIC EDITION

TORTORA | DERRICKSON

BURKETT | DYE | COOKE
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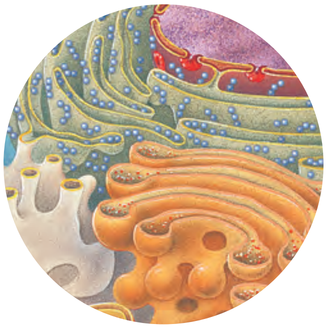

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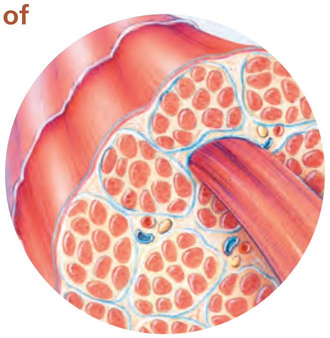

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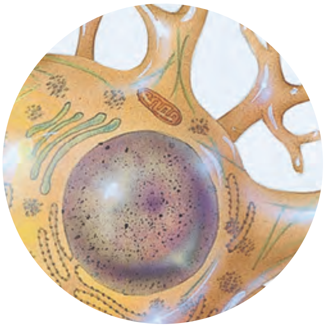

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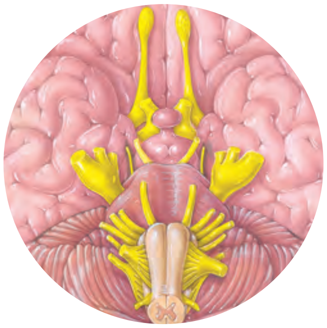

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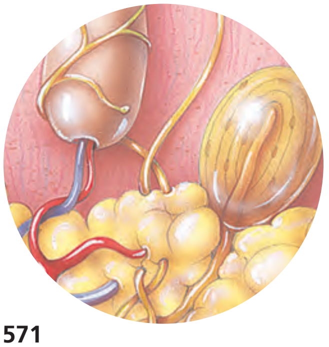

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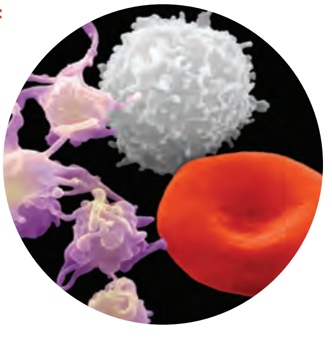

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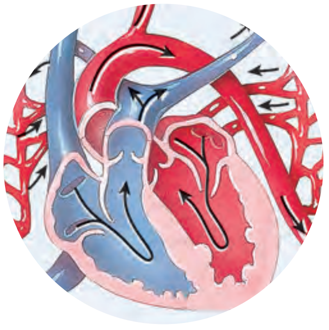

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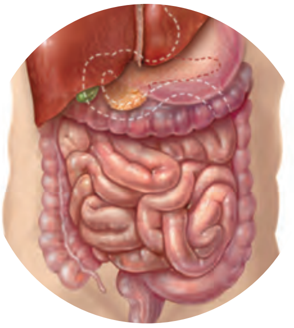

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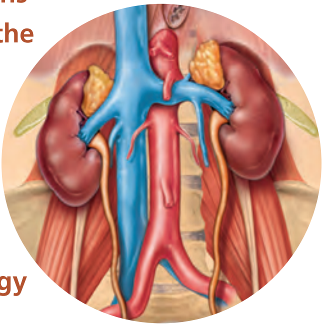

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PREFACE

Creating the first ever Asia–Pacific edition of an anatomy and physiology resource has been an exciting ride! As a multidisciplinary author team we are bound by a common passion to make the anatomy and physiology course a springboard to a rewarding career in a range of health-related professions. We have created an extensive body of features that bring anatomy and physiology concepts to life through sport, exercise science and clinical scenarios students will easily relate to. The central theme of this resource — homeostasis — is a universal one, but we have strived to deliver deeper student engagement and understanding through the context, examples and applications we have highlighted from our local region.

We couldn't have built a resource of this magnitude on our own, and would like to extend our heartfelt thanks to all our academic colleagues who reviewed our work, the participants of our digital advisory boards and the attendees of Wiley's 'Insights into improving student outcomes and increasing retention in A&P' events. We would also like to thank Jerry Tortora and Bryan Derrickson for the outstanding source material, and the team at Wiley Australia for their support and encouragement throughout this journey. Wiley's commitment to affordability in this subject area is something we warmly welcome as an author team who want to see our resource as accessible as possible for students in our region. Special thanks to Terry Burkitt (Publishing Manager), Kylie Challenor (Managing Content Editor), Rebecca Cam (Digital Content Editor), Anne-Marie Seymour (National Marketing Manager), Delia Sala (Graphic Designer) and Jo Hawthorne (Senior Composition Coordinator).

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Above all, Jerry is devoted to his students and their aspirations. In recognition of this commitment, Jerry was the recipient of MACUB's 1992 President's Memorial Award. In 1996, he received a National Institute for Staff and Organizational Development (NISOD) excellence award from the University of Texas and was selected to represent Bergen Community College in a campaign to increase awareness of the contributions of community colleges to higher education.

Jerry is the author of several best-selling science textbooks and laboratory manuals, a calling that often requires an additional 40 hours per week beyond his teaching responsibilities. Nevertheless, he still makes time for four or five weekly aerobic workouts that include biking and running. He also enjoys attending college basketball and professional hockey games and performances at the Metropolitan Opera House.

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Brendan Burkett (OAM) is a professional engineer, a Professor in Biomechanics at the University of the Sunshine Coast, and a Paralympic swimming champion. Brendan competed at 4 Paralympic Games and won several medals, leading the Australian team into the opening ceremony at the Sydney 2000 Games. The combination of engineering and human movement qualifications, along with sporting experience, has provided Brendan with a solid understanding of human anatomy and the requirements for 'sport spotlights'. His focus on sports technology for people with disability is recognised through his Institution of Engineers, Australia, award in 2000 for Professional Engineer of the Year, and by his participation in the 2008 Prime Minister's 2020 Summit.

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Rebecca Mellifont is a Senior Lecturer in Sport Science (Anatomy) at the University of the Sunshine Coast. She completed her postdoctoral studies at the Sport Science Institute of South Africa in Cape Town, and in 2011 completed a Graduate Certificate of Professional Learning. Rebecca's interests have developed from her PhD research in comparative anatomy, and her current research interests lie in the study of the biomechanics and three-dimensional gait analysis in children and sport applications, particularly swimming technique (and race analysis). Rebecca has been a biomechanist and sport scientist for the Australian Paralympic Swim Team, and has an interest in the scholarship of teaching and developing ways to improve the delivery and uptake of material (lecture and practical) in a higher education setting.

Latika Samalia is a Professional Practice Fellow at the Anatomy Department of the University of Otago, Dunedin, New Zealand, where she teaches clinical anatomy in a number of undergraduate and postgraduate professional courses. She teaches the early and advanced learning in medicine, head and neck anatomy to dental students, and musculoskeletal and reproductive anatomy to physiotherapy and pharmacy students. Latika received her medical degree (DSM) from the Fiji School of Medicine and her postgraduate degree in Science in Anatomy from the University of Otago.

After practising obstetrics and gynaecology for a number of years, she took up academia. Latika has been instrumental in initiating and running a number of postgraduate anatomy workshops in her department, focusing on various clinical disciplines. She is passionate in promoting clinical anatomy education and is a highly devoted teacher, having been rewarded with several student and university teaching awards.

Gregory Peoples (Bachelor of Biomedical Science, first class honours; PhD) is currently a Senior Lecturer in the School of Medicine at the University of Wollongong. His primary training is medical science with a particular research focus on exercise and nutritional physiology. His research publications have emphasised the important role of omega-3 fish oil in the human diet to optimise heart and skeletal muscle function. Gregory has ten years' experience coordinating and lecturing undergraduate human anatomy and physiology at the University of Wollongong. His programs have been designed and implemented for students studying courses in exercise science and nutrition and have an emphasis on the applied nature of these professions, underpinned with a sound application of science.

HOW TO USE THIS RESOURCE

15 The autonomic nervous system

The autonomic nervous system and homeostasis

The autonomic nervous system contributes to homeostasis by responding to subconscious visceral sensations and exciting or inhibiting smooth muscle, cardiac muscle, and glands.

In this chapter, the peripheral nervous system is divided into somatic nervous system (SNS) and autonomic nervous system (ANS). Like the somatic nervous system, the autonomic nervous system (ANS) (aw´-tō-NOM-ik) operates via reflex arcs. (The derivation is auto- = self; -nomic = law.) Structurally, the ANS includes autonomic sensory neurons, integrating centres in the central nervous system (CNS), autonomic motor neurons, and the enteric division or enteric nervous system (ENS).

A continual flow of nerve impulses from (1) autonomic sensory neurons in visceral organs and blood vessels propagate into (2) integrating centres in the CNS. Then, impulses in (3) autonomic motor neurons propagate to various effector tissues, thereby regulating the activity of smooth muscle, cardiac muscle, and many glands. The ANS usually operates without conscious control.

The Rugby Union's Bledisloe Cup is played annually between the New Zealand All Blacks and Australian Wallabies. The cup was donated by Lord Bledisloe, former Governor-General of New Zealand, in 1931. The All Blacks team performs a 'Haka' at the beginning of all rugby matches — a traditional Māori ceremonial war dance. This is an activity adopted by the New Zealand rugby players prior to competitions as a challenge to the opposition. The players in black — the All Blacks — are all charged with high energy. They are reciting the Haka in excitement, jumping, their eyes are wide open with dilated pupils. The players have an elevated heart rate and blood pressure and increased perspiration as well. These signs are all due to sympathetic nervous system stimulation.

The sympathetic nervous system is one of the two divisions of the autonomic nervous system. It is responsible for the 'fight or flight' response, the physiologic changes that occur during a state of emergency or stress. These physiologic changes give the subject added strength during emergency states. In the case of these players, it is the anticipation of the game and physical stress that causes an increase in sympathetic outflow. The parasympathetic system works opposite to the sympathetic nervous system and controls physiologic activities opposite those seen in these excited rugby players at the beginning of the Bledisloe cup.

***Did you ever wonder** how some blood pressure medications exert their effects through the autonomic nervous system*

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A short **opening case** frames the context of the chapter using a real-world clinical or sports example relevant to Australia, New Zealand and the Asia–Pacific.

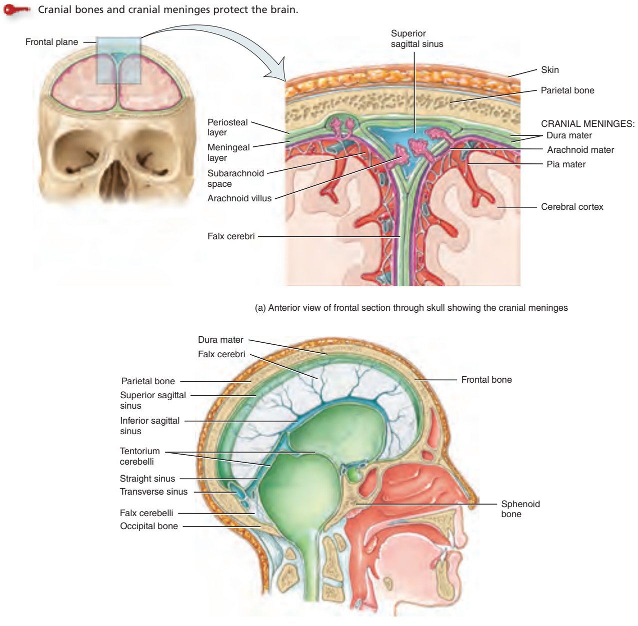
14.1 BRAIN ORGANISATION, PROTECTION, AND BLOOD SUPPLY 489

Protective coverings of the brain

The cranium (see figure 7.4) and the cranial meninges surround and protect the brain. The **cranial meninges** (me-NIN-jēz) are continuous with the spinal meninges, have the same basic structure, and bear the same names: the outer **dura mater** (DOO-ra MĀ-ter), the middle **arachnoid mater** (a-RAK-noyd), and the inner **pia mater** (PĒ-a or PĪ-a) (figure 14.2). However, the cranial dura mater has two layers; the spinal dura mater has only one. The two dural layers are called the *periosteal layer* (which is external) and the *meningeal layer* (which is internal).

Figure 14.2 The protective coverings of the brain.

Cranial bones and cranial meninges protect the brain.



What are the three layers of the cranial meninges, from superficial to deep?

CHAPTER 14

Impacting visuals highlight key anatomical structures and functions, including the importance of homeostasis and the mechanisms that support it, using easy-to-understand figures, exhibits and tables.

18.11 OVARIES AND TESTES 663

CLINICAL CONNECTION | *New technology in type 1 diabetes*

Type 1 diabetes makes up 10–15 per cent of all diabetes cases. The discovery of insulin nearly 100 years ago has now informed best practice in managing and potentially treating type 1 diabetes. Management of type 1 diabetes has centred on the monitoring of blood sugar levels. Adjustments then focus on a combination of diet to deliver carbohydrates, the regulation of physical activity, and then the injection of insulin to aid in the uptake of glucose into the cells of the body. For a person living with type 1 diabetes, this is a lifelong cycle occurring multiple times per day. As such, modern medicine has been focused on how to replace the failed pancreatic beta cells responsible for natural insulin secretion.

Pancreatic islet cell transplant is one strategy that would allow the pancreas to resume the role of glucose maintenance. Given that the mass of these cells is as little as 1–2 per cent of the entire pancreas, the task of cell isolation is challenging. Key aspects of the transplant process to date has been the cell technology in collecting islet cells in large enough numbers. Combined with state-of-the-art immunosuppressant therapy, early success has been demonstrated with patients regaining metabolic control. At the Garvan Institute of Medical Research, Sydney, the question of how to replace the islet cells without coming under attack from the immune system of the patient is one key area of research. Early studies involving animal models suggest that blocking the work of immune function T cells will allow the survival of the transplanted pancreatic beta cells. In other words, they can be surgically placed into the pancreas of the type 1 diabetic and remain undetected from the natural immune system.

The future treatment of type 1 diabetes look promising. Given that the disease strikes most often in early childhood, this type of cell transplant and combination therapy will literally result in a lifetime change for people.[4]

CHECKPOINT

21. How are blood levels of glucagon and insulin controlled?
22. What are the effects of exercise versus eating a carbohydrate- and protein-rich meal on the secretion of insulin and glucagon?

18.11 Ovaries and testes

OBJECTIVE

- Describe the location, hormones, and functions of the male and female gonads.

Gonads are the organs that produce gametes — sperm in males and oocytes in females. In addition to their reproductive function, the gonads secrete hormones. The **ovaries**, paired oval bodies located in the female pelvic cavity, produce several steroid hormones, including two **oestrogens** (estradiol and estrone) and **progesterone**. These female sex hormones, along with follicle-stimulating hormone (FSH) and luteinising hormone (LH) from the anterior pituitary, regulate the menstrual cycle, maintain pregnancy, and prepare the mammary glands for lactation. They also promote enlargement of the breasts and widening of the hips at puberty, and help maintain these female secondary sex characteristics. The ovaries also produce **inhibin**, a protein hormone that inhibits secretion of FSH. During pregnancy, the ovaries and placenta produce a peptide hormone called **relaxin (RLX)**, which increases the flexibility of the pubic symphysis during pregnancy and helps dilate the uterine cervix during labour and delivery. These actions help ease the baby's passage by enlarging the birth canal.

The male gonads, the **testes**, are oval glands that lie in the scrotum. The main hormone produced and secreted by the testes is **testosterone**, an **androgen** or male sex hormone. Testosterone stimulates descent of the testes before birth, regulates production of sperm, and stimulates the development and maintenance of male secondary sex characteristics, such as beard growth and deepening of the voice. The testes also produce inhibin, which inhibits secretion of FSH. The detailed structure of the ovaries and testes and the specific roles of sex hormones are discussed in chapter 28.

Table 18.10 summarises the hormones produced by the ovaries and testes and their principal actions.

TABLE 18.10

Summary of hormones of the ovaries and testes

HORMONE	PRINCIPAL ACTIONS
OVARIAN HORMONES	
Oestrogens and progesterone (Ovary)	Together with gonadotropic hormones of anterior pituitary, regulate female reproductive cycle, maintain pregnancy, prepare mammary glands for lactation, and promote development and maintenance of female secondary sex characteristics.
Relaxin (RLX)	Increases flexibility of pubic symphysis during pregnancy; helps dilate uterine cervix during labour and delivery.
Inhibin	Inhibits secretion of FSH from anterior pituitary.
TESTICULAR HORMONES	
Testosterone (Testis)	Stimulates descent of testes before birth; regulates sperm production; promotes development and maintenance of male secondary sex characteristics.
Inhibin	Inhibits secretion of FSH from anterior pituitary.

CHAPTER 18

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tissue, areolar connective tissue, and blood vessels. Collectively, the vertebral foramina of all vertebrae form the *vertebral (spinal) canal*. The pedicles exhibit superior and inferior indentations called *vertebral notches*. When the vertebral notches are stacked on top of one another, they form an opening between adjoining vertebrae on both sides of the column. Each opening, called an *intervertebral foramen*, permits the passage of a single spinal nerve carrying information to and from the spinal cord.

Processes

Seven **processes** arise from the vertebral arch. At the point where a lamina and pedicle join, a *transverse process* extends laterally on each side. A single *spinous process (spine)* projects posteriorly from the junction of the laminae. These three processes serve as points of attachment for muscles. The remaining four processes form joints with other vertebrae above or below. The two *superior articular processes* of a vertebra articulate (form joints) with the two inferior articular processes of the vertebra immediately above them. In turn, the two *inferior articular processes* of that vertebra articulate with the two superior articular processes of the vertebra immediately below them, and so on. The articulating surfaces of the articular processes, which are referred to as *facets* (FAS-ets or fa-SETS = little faces), are covered with hyaline cartilage. The articulations formed between the vertebral bodies and articular facets of successive vertebrae are termed *intervertebral joints.*

SPORT SPOTLIGHT | *Crouch, bind, set!*

New Zealand's Accident Compensation Corporation (ACC) paid out almost $64 million for rugby union injuries during the 2012–13 financial year. Competitive scrummaging is a valued aspect of New Zealand's national game, but plays a role in this significant injury toll. Scrums require a pack of forwards to provide forceful and coordinated collisions at low body height to provide a platform for ball possession. Due to the physical brutality of this phase of play, if executed awkwardly scrums can pose a risk of chronic degenerative injuries to the spine. On very rare occasions, catastrophic cervical spine injuries do occur.

From the junior rugby level, players are educated to use a 'mayday' call — a safety technique used when a player considers a scrum to be collapsing, or when they believe they are in a dangerous position. When the 'mayday' call is sounded, other members of the scrum are encouraged to repeat the call to ensure it is heard by members of both teams and the referee. All players immediately stop pushing to release pressure on the front row and drop to their knees. The front row then simultaneously lands their faces on the ground to protect their necks. The scrum is slowly disassembled from the outside in. A recent All Blacks versus Wallabies match in Sydney was the first match played under a new rule to reduce risk to players in the scrum. The amended referee language to engage both sides of the scrum — 'crouch, bind, set' — requires players to first bind arms before colliding, increasing balance and decreasing the risk of serious spinal injuries.[4]

Regions of the vertebral column

Exhibits 7.H through 7.K present the five regions of the vertebral column, beginning superiorly and moving inferiorly. The regions are the cervical, thoracic, lumbar, sacral, and coccygeal. Note that vertebrae in each region are numbered in sequence, from superior to inferior. When you actually view the bones of the vertebral column, you will notice that the transition from one region to the next is not abrupt but gradual, a feature that helps the vertebrae fit together.

Age-related changes in the vertebral column

With advancing age the vertebral column undergoes changes that are characteristic of the skeletal system in general. These changes include reduction in the mass and density of the bone along with a reduction in the collagen-to-mineral content within the bone, changes that make the bones more brittle and susceptible to damage. The articular surfaces, those surfaces where neighbouring bones move against one another, lose their covering cartilage as they age; in their place rough bony growths form that lead to arthritic conditions. In the vertebral column, bony growths around the intervertebral discs, called *osteophytes*, can lead to a narrowing (stenosis) of the vertebral canal. This narrowing can lead to compression of spinal nerves and the spinal cord, which can manifest as pain and decreased muscle function in the back and lower limbs.

CHECKPOINT

16. What are the functions of the vertebral column?
17. Describe the four curves of the vertebral column.
18. What are the three main parts of a typical vertebra?
19. What are the principal distinguishing characteristics of the bones of the various regions of the vertebral column?

7.7 Thorax

OBJECTIVE

- Identify the bones of the thorax and their functions.

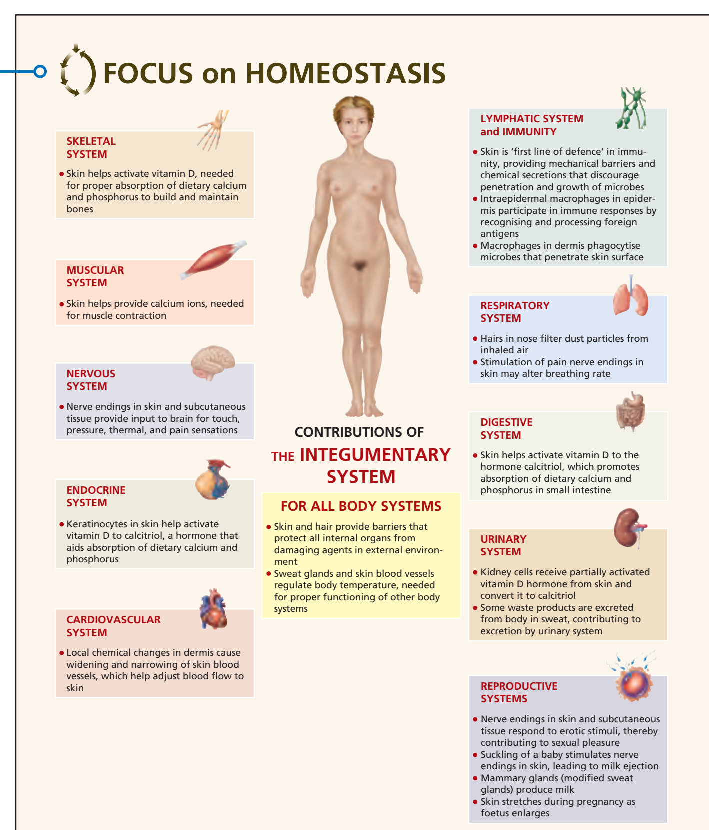
The term **thorax** refers to the entire chest region. The skeletal part of the thorax, the **thoracic cage,** is a bony enclosure formed by the sternum, ribs and their costal cartilages, and the bodies of the thoracic vertebrae (see exhibits 7.L and 7.M). The costal cartilages attach the ribs to the sternum. The thoracic cage is narrower at its superior end and broader at its inferior end and is flattened from front to back. It encloses and protects the organs in the thoracic and superior abdominal cavities, provides support for the bones of the upper limbs, and, as you will see in chapter 23, plays a role in breathing.

CHECKPOINT

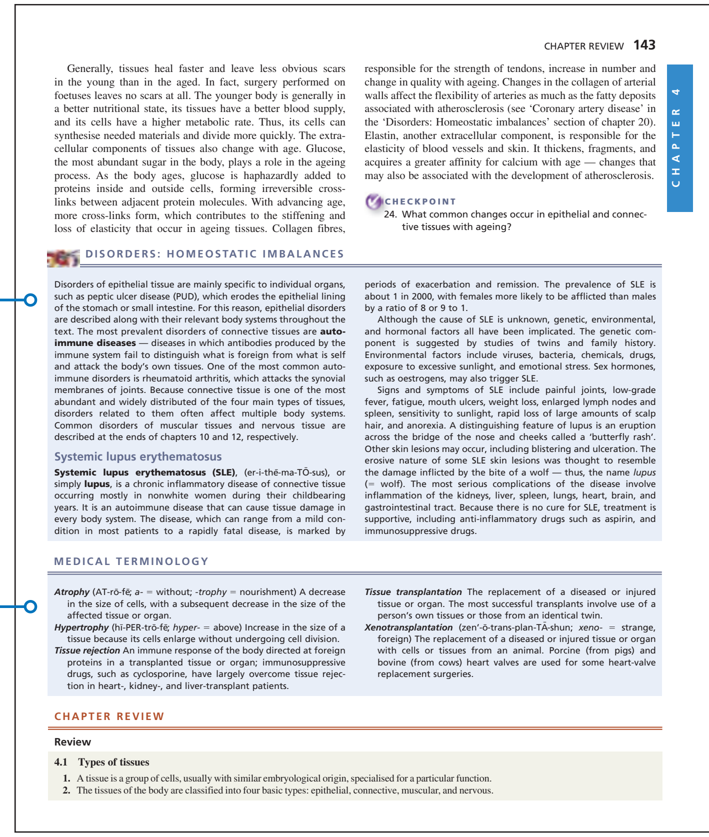
20. What bones form the skeleton of the thorax?
21. What are the functions of the bones of the thorax?
22. How are ribs classified?

Clinical Connection and **Sport Spotlight** vignettes help students understand the relevance of anatomical structures and functions using practical allied health and sports examples specific to Australian, New Zealand and Asia–Pacific audiences.

Following selected chapters, **Focus on Homeostasis** fosters understanding of how each body system contributes to overall homeostasis through its interaction with other systems.



Most chapters in the text are followed by concise discussions of major **disorders** illustrating departures from normal homeostasis, as well as a glossary of key **medical terminology** including both normal and pathological conditions.



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Generally, tissues heal faster and leave less obvious scars in the young than in the aged. In fact, surgery performed on foetuses leaves no scars at all. The younger body is generally in a better nutritional state, its tissues have a better blood supply, and its cells have a higher metabolic rate. Thus, its cells can synthesise needed materials and divide more quickly. The extracellular components of tissues also change with age. Glucose, the most abundant sugar in the body, plays a role in the ageing process. As the body ages, glucose is haphazardly added to proteins inside and outside cells, forming irreversible cross-links between adjacent protein molecules. With advancing age, more cross-links form, which contributes to the stiffening and loss of elasticity that occur in ageing tissues. Collagen fibres, responsible for the strength of tendons, increase in number and change in quality with ageing. Changes in the collagen of arterial walls affect the flexibility of arteries as much as the fatty deposits associated with atherosclerosis (see 'Coronary artery disease' in the 'Disorders: Homeostatic imbalances' section of chapter 20). Elastin, another extracellular component, is responsible for the elasticity of blood vessels and skin. It thickens, fragments, and acquires a greater affinity for calcium with age — changes that may also be associated with the development of atherosclerosis.

CHECKPOINT

24. What common changes occur in epithelial and connective tissues with ageing?

CHAPTER 4

DISORDERS: HOMEOSTATIC IMBALANCES

Disorders of epithelial tissue are mainly specific to individual organs, such as peptic ulcer disease (PUD), which erodes the epithelial lining of the stomach or small intestine. For this reason, epithelial disorders are described along with their relevant body systems throughout the text. The most prevalent disorders of connective tissues are **autoimmune diseases** — diseases in which antibodies produced by the immune system fail to distinguish what is foreign from what is self and attack the body's own tissues. One of the most common autoimmune disorders is rheumatoid arthritis, which attacks the synovial membranes of joints. Because connective tissue is one of the most abundant and widely distributed of the four main types of tissues, disorders related to them often affect multiple body systems. Common disorders of muscular tissues and nervous tissue are described at the ends of chapters 10 and 12, respectively.

Systemic lupus erythematosus

Systemic lupus erythematosus (SLE), (er-i-thé-ma-TŌ-sus), or simply **lupus**, is a chronic inflammatory disease of connective tissue occurring mostly in nonwhite women during their childbearing years. It is an autoimmune disease that can cause tissue damage in every body system. The disease, which can range from a mild condition in most patients to a rapidly fatal disease, is marked by periods of exacerbation and remission. The prevalence of SLE is about 1 in 2000, with females more likely to be afflicted than males by a ratio of 8 or 9 to 1.

Although the cause of SLE is unknown, genetic, environmental, and hormonal factors all have been implicated. The genetic component is suggested by studies of twins and family history. Environmental factors include viruses, bacteria, chemicals, drugs, exposure to excessive sunlight, and emotional stress. Sex hormones, such as oestrogens, may also trigger SLE.

Signs and symptoms of SLE include painful joints, low-grade fever, fatigue, mouth ulcers, weight loss, enlarged lymph nodes and spleen, sensitivity to sunlight, rapid loss of large amounts of scalp hair, and anorexia. A distinguishing feature of lupus is an eruption across the bridge of the nose and cheeks called a 'butterfly rash'. Other skin lesions may occur, including blistering and ulceration. The erosive nature of some SLE skin lesions was thought to resemble the damage inflicted by the bite of a wolf — thus, the name *lupus* (= wolf). The most serious complications of the disease involve inflammation of the kidneys, liver, spleen, lungs, heart, brain, and gastrointestinal tract. Because there is no cure for SLE, treatment is supportive, including anti-inflammatory drugs such as aspirin, and immunosuppressive drugs.

MEDICAL TERMINOLOGY

Atrophy (AT-rō-fē; *a-* = without; *-trophy* = nourishment) A decrease in the size of cells, with a subsequent decrease in the size of the affected tissue or organ.

Hypertrophy (hī-PER-trō-fē; *hyper-* = above) Increase in the size of a tissue because its cells enlarge without undergoing cell division.

Tissue rejection An immune response of the body directed at foreign proteins in a transplanted tissue or organ; immunosuppressive drugs, such as cyclosporine, have largely overcome tissue rejection in heart-, kidney-, and liver-transplant patients.

Tissue transplantation The replacement of a diseased or injured tissue or organ. The most successful transplants involve use of a person's own tissues or those from an identical twin.

Xenotransplantation (zen'-ō-trans-plan-TĀ-shun; *xeno-* = strange, foreign) The replacement of a diseased or injured tissue or organ with cells or tissues from an animal. Porcine (from pigs) and bovine (from cows) heart valves are used for some heart-valve replacement surgeries.

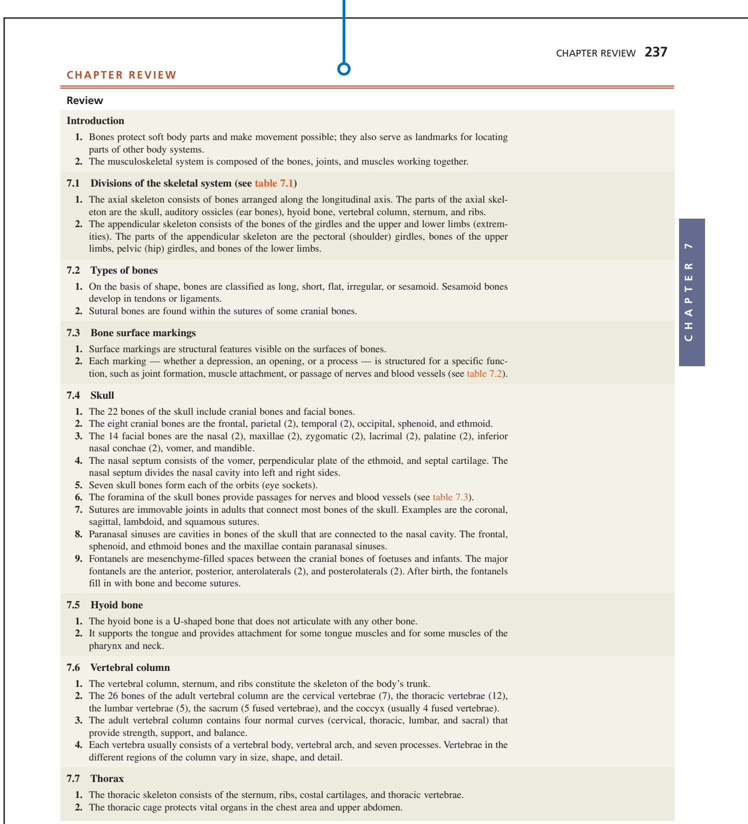
CHAPTER REVIEW

Review

4.1 Types of tissues

1. A tissue is a group of cells, usually with similar embryological origin, specialised for a particular function.
2. The tissues of the body are classified into four basic types: epithelial, connective, muscular, and nervous.

Each chapter concludes with a **chapter review** summarising key concepts, as well as **critical thinking questions** and **answers to figure questions**.



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CHAPTER REVIEW

Review

Introduction

1. Bones protect soft body parts and make movement possible; they also serve as landmarks for locating parts of other body systems.
2. The musculoskeletal system is composed of the bones, joints, and muscles working together.

7.1 Divisions of the skeletal system (see table 7.1)

1. The axial skeleton consists of bones arranged along the longitudinal axis. The parts of the axial skeleton are the skull, auditory ossicles (ear bones), hyoid bone, vertebral column, sternum, and ribs.
2. The appendicular skeleton consists of the bones of the girdles and the upper and lower limbs (extremities). The parts of the appendicular skeleton are the pectoral (shoulder) girdles, bones of the upper limbs, pelvic (hip) girdles, and bones of the lower limbs.

7.2 Types of bones

1. On the basis of shape, bones are classified as long, short, flat, irregular, or sesamoid. Sesamoid bones develop in tendons or ligaments.
2. Sutural bones are found within the sutures of some cranial bones.

7.3 Bone surface markings

1. Surface markings are structural features visible on the surfaces of bones.
2. Each marking — whether a depression, an opening, or a process — is structured for a specific function, such as joint formation, muscle attachment, or passage of nerves and blood vessels (see table 7.2).

7.4 Skull

1. The 22 bones of the skull include cranial bones and facial bones.
2. The eight cranial bones are the frontal, parietal (2), temporal (2), occipital, sphenoid, and ethmoid.
3. The 14 facial bones are the nasal (2), maxillae (2), zygomatic (2), lacrimal (2), palatine (2), inferior nasal conchae (2), vomer, and mandible.
4. The nasal septum consists of the vomer, perpendicular plate of the ethmoid, and septal cartilage. The nasal septum divides the nasal cavity into left and right sides.
5. Seven skull bones form each of the orbits (eye sockets).
6. The foramina of the skull bones provide passages for nerves and blood vessels (see table 7.3).
7. Sutures are immovable joints in adults that connect most bones of the skull. Examples are the coronal, sagittal, lambdoid, and squamous sutures.
8. Paranasal sinuses are cavities in bones of the skull that are connected to the nasal cavity. The frontal, sphenoid, and ethmoid bones and the maxillae contain paranasal sinuses.
9. Fontanels are mesenchyme-filled spaces between the cranial bones of foetuses and infants. The major fontanels are the anterior, posterior, anterolaterals (2), and posterolaterals (2). After birth, the fontanels fill in with bone and become sutures.

7.5 Hyoid bone

1. The hyoid bone is a U-shaped bone that does not articulate with any other bone.
2. It supports the tongue and provides attachment for some tongue muscles and for some muscles of the pharynx and neck.

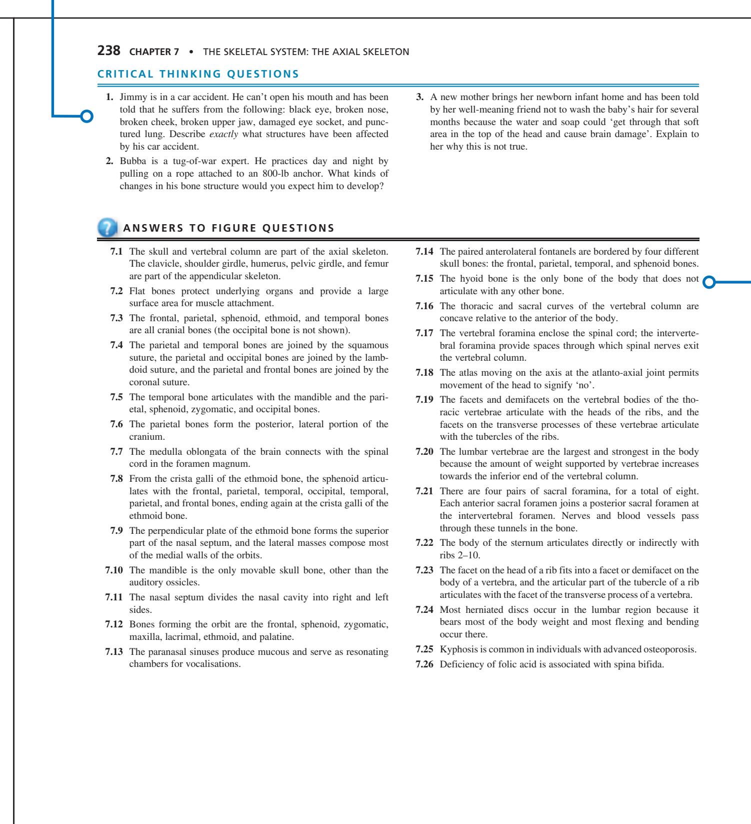
7.6 Vertebral column

1. The vertebral column, sternum, and ribs constitute the skeleton of the body's trunk.
2. The 26 bones of the adult vertebral column are the cervical vertebrae (7), the thoracic vertebrae (12), the lumbar vertebrae (5), the sacrum (5 fused vertebrae), and the coccyx (usually 4 fused vertebrae).
3. The adult vertebral column contains four normal curves (cervical, thoracic, lumbar, and sacral) that provide strength, support, and balance.
4. Each vertebra usually consists of a vertebral body, vertebral arch, and seven processes. Vertebrae in the different regions of the column vary in size, shape, and detail.

7.7 Thorax

1. The thoracic skeleton consists of the sternum, ribs, costal cartilages, and thoracic vertebrae.
2. The thoracic cage protects vital organs in the chest area and upper abdomen.

CHAPTER 7



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CRITICAL THINKING QUESTIONS

1. Jimmy is in a car accident. He can't open his mouth and has been told that he suffers from the following: black eye, broken nose, broken cheek, broken upper jaw, damaged eye socket, and punctured lung. Describe *exactly* what structures have been affected by his car accident.
2. Bubba is a tug-of-war expert. He practices day and night by pulling on a rope attached to an 800-lb anchor. What kinds of changes in his bone structure would you expect him to develop?
3. A new mother brings her newborn infant home and has been told by her well-meaning friend not to wash the baby's hair for several months because the water and soap could 'get through that soft area in the top of the head and cause brain damage'. Explain to her why this is not true.

ANSWERS TO FIGURE QUESTIONS

7.1 The skull and vertebral column are part of the axial skeleton. The clavicle, shoulder girdle, humerus, pelvic girdle, and femur are part of the appendicular skeleton.

7.2 Flat bones protect underlying organs and provide a large surface area for muscle attachment.

7.3 The frontal, parietal, sphenoid, ethmoid, and temporal bones are all cranial bones (the occipital bone is not shown).

7.4 The parietal and temporal bones are joined by the squamous suture, the parietal and occipital bones are joined by the lambdoid suture, and the parietal and frontal bones are joined by the coronal suture.

7.5 The temporal bone articulates with the mandible and the parietal, sphenoid, zygomatic, and occipital bones.

7.6 The parietal bones form the posterior, lateral portion of the cranium.

7.7 The medulla oblongata of the brain connects with the spinal cord in the foramen magnum.

7.8 From the crista galli of the ethmoid bone, the sphenoid articulates with the frontal, parietal, temporal, occipital, temporal, parietal, and frontal bones, ending again at the crista galli of the ethmoid bone.

7.9 The perpendicular plate of the ethmoid bone forms the superior part of the nasal septum, and the lateral masses compose most of the medial walls of the orbits.

7.10 The mandible is the only movable skull bone, other than the auditory ossicles.

7.11 The nasal septum divides the nasal cavity into right and left sides.

7.12 Bones forming the orbit are the frontal, sphenoid, zygomatic, maxilla, lacrimal, ethmoid, and palatine.

7.13 The paranasal sinuses produce mucous and serve as resonating chambers for vocalisations.

7.14 The paired anterolateral fontanels are bordered by four different skull bones: the frontal, parietal, temporal, and sphenoid bones.

7.15 The hyoid bone is the only bone of the body that does not articulate with any other bone.

7.16 The thoracic and sacral curves of the vertebral column are concave relative to the anterior of the body.

7.17 The vertebral foramina enclose the spinal cord; the intervertebral foramina provide spaces through which spinal nerves exit the vertebral column.

7.18 The atlas moving on the axis at the atlanto-axial joint permits movement of the head to signify 'no'.

7.19 The facets and demifacets on the vertebral bodies of the thoracic vertebrae articulate with the heads of the ribs, and the facets on the transverse processes of these vertebrae articulate with the tubercles of the ribs.

7.20 The lumbar vertebrae are the largest and strongest in the body because the amount of weight supported by vertebrae increases towards the inferior end of the vertebral column.

7.21 There are four pairs of sacral foramina, for a total of eight. Each anterior sacral foramen joins a posterior sacral foramen at the intervertebral foramen. Nerves and blood vessels pass through these tunnels in the bone.

7.22 The body of the sternum articulates directly or indirectly with ribs 2–10.

7.23 The facet on the head of a rib fits into a facet or demifacet on the body of a vertebra, and the articular part of the tubercle of a rib articulates with the facet of the transverse process of a vertebra.

7.24 Most herniated discs occur in the lumbar region because it bears most of the body weight and most flexing and bending occur there.

7.25 Kyphosis is common in individuals with advanced osteoporosis.

7.26 Deficiency of folic acid is associated with spina bifida.

1 An introduction to the human body

The human body and homeostasis

Humans have many ways to maintain homeostasis, the state of relative stability of the body's internal environment. Disruptions to homeostasis often set in motion corrective cycles, called feedback systems, that help restore the conditions needed for health and life.

Our author team, comprising pre-eminent academics from Australia, New Zealand and the Asia–Pacific, will take you on a remarkable journey through the human body — beginning with an overview of the meanings of anatomy and physiology, followed by a discussion of the organisation of the human body and the properties that it shares with all living things. Next, you will discover how the body regulates its own internal environment. This unceasing process — called homeostasis — is a major theme in every chapter of this resource. Finally, we introduce the vocabulary that will help you speak about the body in a way that is understood by scientists and healthcare professionals alike.

Homeostatis is a universal concept that our local author team has brought to life through an exciting series of sporting, exercise science and clinical scenarios that you will easily relate to. Take, for example, how dehydration affects brain performance for Formula 1 racers like Mark Webber, or how the Australian Cancer Council's SunSmart program demonstrates the functions of the integumentary system (skin). We explore why fast bowlers and ballet dancers so frequently suffer from stress fractures, how research by the University of Queensland established the cervical cancer vaccine, and even how the New Zealand rugby team's Haka stimulates nerve impulses.

***Did you ever wonder* why an autopsy is performed?**

1.1 Anatomy and physiology defined

OBJECTIVE

- Define anatomy and physiology, and name several branches of these sciences.

Two branches of science — anatomy and physiology — provide the foundation for understanding the body's parts and functions. **Anatomy** (a-NAT-ō-mē; *ana-* = up; *-tomy* = process of cutting) is the science of body *structures* and the relationships among them. It was first studied by **dissection** (dis-SEK-shun; *dis-* = apart; *-section* = act of cutting), the careful cutting apart of body structures to study their relationships. Today, a variety of imaging techniques (see table 1.3) also contribute to the advancement of anatomical knowledge. Whereas anatomy deals with structures of the body, **physiology** (fiz′-ē-OL-ō-jē; *physio-* = nature; *-logy* = study of) is the science of body *functions* — how the body parts work. Table 1.1 describes several branches of anatomy and physiology.

Because structure and function are so closely related, you will learn about the human body by studying its anatomy and physiology together. The structure of a part of the body often reflects its functions. For example, the bones of the skull join tightly to form a rigid case that protects the brain. The bones of the fingers are more loosely joined to allow a variety of movements. The walls of the air sacs in the lungs are very thin, permitting rapid movement of inhaled oxygen into the blood.

CHECKPOINT

1. What body function might a respiratory therapist strive to improve? What structures are involved?
2. Give your own example of how the structure of a part of the body is related to its function.

1.2 Levels of structural organisation and body systems

OBJECTIVES

- Describe the body's six levels of structural organisation.
- List the 11 systems of the human body, representative organs present in each, and their general functions.

TABLE 1.1

Selected branches of anatomy and physiology

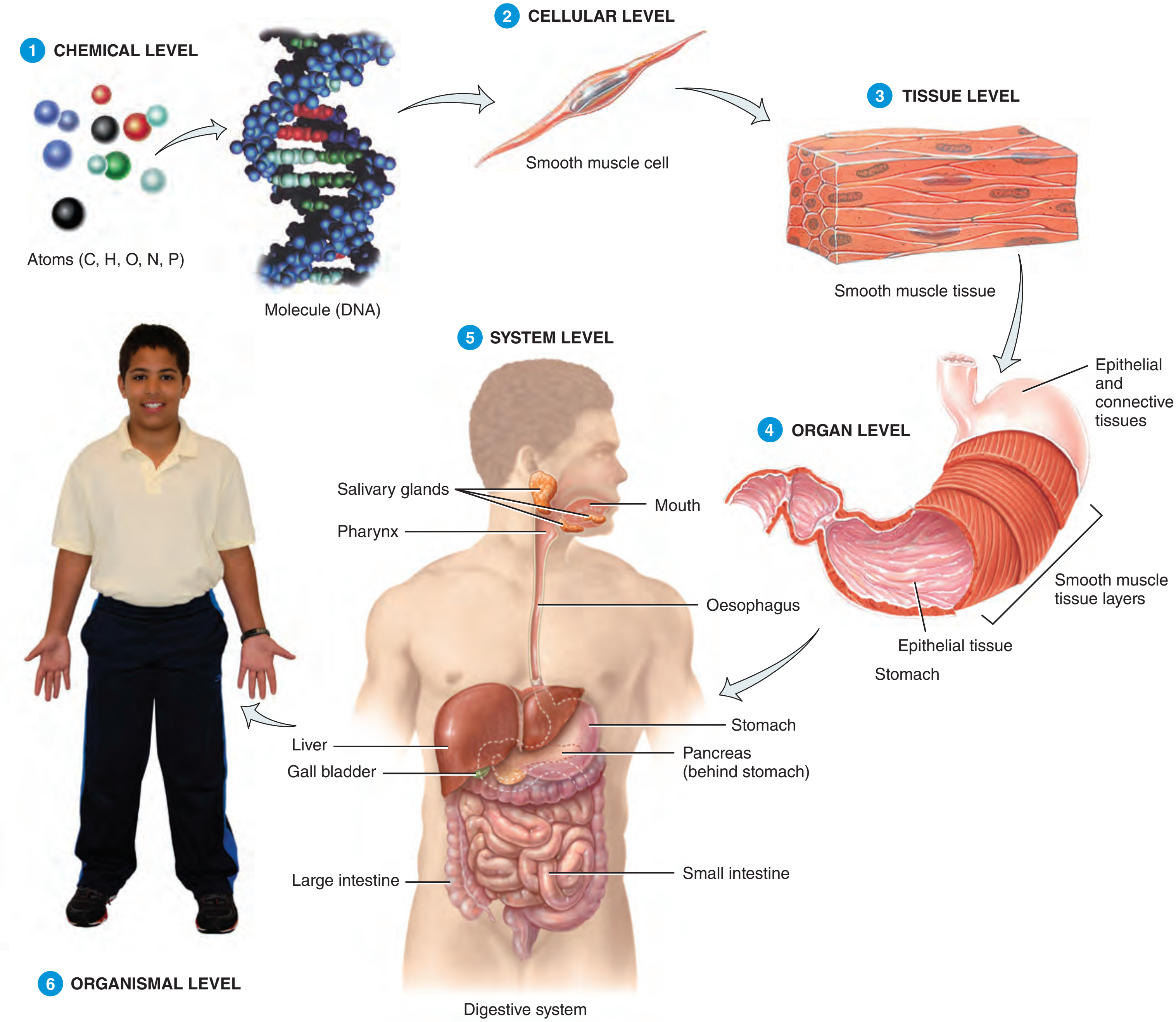
BRANCH OF ANATOMY	STUDY OF	BRANCH OF PHYSIOLOGY	STUDY OF
Embryology (em′-brē-OL-ō-jē; *embry-* = embryo; *-logy* = study of)	The first eight weeks of development after fertilisation of a human egg.	**Neurophysiology** (NOOR-ō-fiz-ē-ol′-ō-jē; *neuro-* = nerve)	Functional properties of nerve cells.
Developmental biology	The complete development of an individual from fertilisation to death.	**Endocrinology** (en′-dō-kri-NOL-ō-jē; *endo-* = within; *-crin* = secretion)	Hormones (chemical regulators in the blood) and how they control body functions.
Cell biology	Cellular structure and functions.	**Cardiovascular physiology** (kar-dē-ō-VAS-kū-lar; *cardi-* = heart; *vascular* = blood vessels)	Functions of the heart and blood vessels.
Histology (his-TOL-ō -jē; *hist-* = tissue)	Microscopic structure of tissues.		
Gross anatomy	Structures that can be examined without a microscope.	**Immunology** (im′-ū-NOL-ō-jē; *immun-* = not susceptible)	The body's defences against disease-causing agents.
Systemic anatomy	Structure of specific systems of the body such as the nervous or respiratory systems.	**Respiratory physiology** (RES-pi-ra-tōr-ē; *respira-* = to breathe)	Functions of the air passageways and lungs.
Regional anatomy	Specific regions of the body such as the head or chest.	**Renal physiology** (RĒ-nal; *ren-* = kidney)	Functions of the kidneys.
Surface anatomy	Surface markings of the body to understand internal anatomy through visualisation and palpation (gentle touch).	**Exercise physiology**	Changes in cell and organ functions due to muscular activity.
Imaging anatomy	Body structures that can be visualised with techniques such as x-rays, MRI, and CT scans.	**Pathophysiology** (Path-ō-fiz-ē-ol′-ō-jē)	Functional changes associated with disease and ageing.
Pathological anatomy (path′-ō-LOJ-i-kal; *path-* = disease)	Structural changes (gross to microscopic) associated with disease.		

The levels of organisation of a language — letters, words, sentences, paragraphs, and so on — can be compared to the levels of organisation of the human body. Your exploration of the human body will extend from atoms and molecules to the whole person. From the smallest to the largest, six levels of organisation will help you to understand anatomy and physiology: the chemical, cellular, tissue, organ, system, and organismal levels of organisation (figure 1.1).

1. **Chemical level.** This very basic level can be compared to the *letters of the alphabet* and includes **atoms**, the smallest units of matter that participate in chemical reactions, and **molecules**, two or more atoms joined together. Certain atoms, such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), calcium (Ca), and sulphur (S), are essential for maintaining life. Two familiar molecules found in the body are deoxyribonucleic acid (DNA), the genetic material passed from one generation to the next, and glucose, commonly known as blood sugar. Chapters 2 and 25 focus on the chemical level of organisation.

Figure 1.1 **Levels of structural organisation in the human body.**

The levels of structural organisation are chemical, cellular, tissue, organ, system, and organismal.



Which level of structural organisation is composed of two or more different types of tissues that work together to perform a specific function?

2 **Cellular level.** Molecules combine to form **cells**, the basic structural and functional units of an organism that are composed of chemicals. Just as *words* are the smallest elements of language that make sense, cells are the smallest living units in the human body. Among the many kinds of cells in your body are muscle cells, nerve cells, and epithelial cells. Figure 1.1 shows a smooth muscle cell, one of the three types of muscle cells in the body. The cellular level of organisation is the focus of chapter 3.

3 **Tissue level. Tissues** are groups of cells and the materials surrounding them that work together to perform a particular function, similar to the way words are put together to form *sentences*. There are just four basic types of tissues in your body: epithelial tissue, connective tissue, muscular tissue, and nervous tissue. *Epithelial tissue* covers body surfaces, lines hollow organs and cavities, and forms glands. *Connective tissue* connects, supports, and protects body organs while distributing blood vessels to other tissues. *Muscular tissue* contracts to make body parts move and generates heat. *Nervous tissue* carries information from one part of the body to another through nerve impulses. Chapter 4 describes the tissue level of organisation in greater detail. Shown in figure 1.1 is smooth muscle tissue, which consists of tightly packed smooth muscle cells.

4 **Organ level.** At the organ level different types of tissues are joined together. Similar to the relationship between sentences and *paragraphs*, **organs** are structures that are composed of two or more different types of tissues; they have specific functions and usually have recognisable shapes. Examples of organs are the stomach, skin, bones, heart, liver, lungs, and brain. Figure 1.1 shows how several tissues make up the stomach. The stomach's outer covering is a layer of epithelial tissue and connective tissue that reduces friction when the stomach moves and rubs against other organs. Underneath are three layers of a type of muscular tissue called *smooth muscle tissue,* which contracts to churn and mix food and then push it into the next digestive organ, the small intestine. The innermost lining is an *epithelial tissue layer* that produces fluid and chemicals responsible for digestion in the stomach.

5 **System level.** A **system** (or *chapter* in our language analogy) consists of related organs (*paragraphs*) with a common function. An example of the system level, also called the *organ-system level,* is the digestive system, which breaks down and absorbs food. Its organs include the mouth, salivary glands, pharynx (throat), oesophagus (food tube), stomach, small intestine, large intestine, liver, gall bladder, and pancreas. Sometimes an organ is part of more than one system. The pancreas, for example, is part of both the digestive system and the hormone-producing endocrine system.

6 **Organismal level.** An **organism** (OR-ga-nizm), any living individual, can be compared to a *book* in our analogy. All the parts of the human body functioning together constitute the total organism.

In the chapters that follow, you will study the anatomy and physiology of the body systems. Table 1.2 lists the components and introduces the functions of these systems. You will also discover

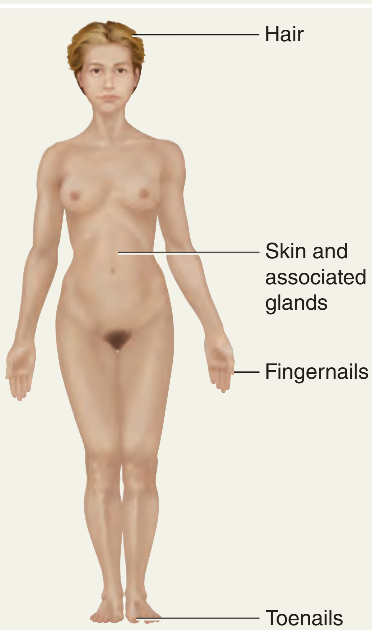
TABLE 1.2

The eleven systems of the human body

INTEGUMENTARY SYSTEM (CHAPTER 5)

Components: **Skin** and associated structures, such as **hair, fingernails** and **toenails, sweat glands,** and **oil glands**.

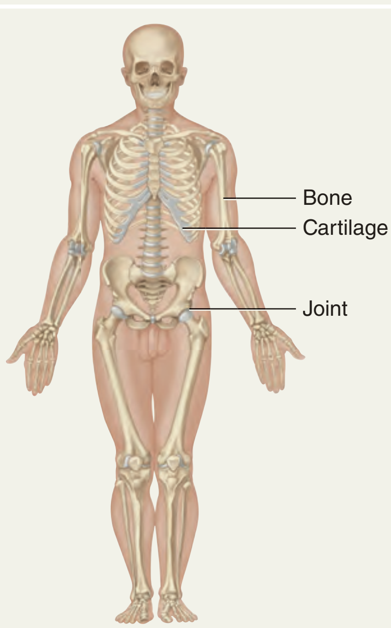
Functions: Protects body; helps regulate body temperature; eliminates some wastes; helps make vitamin D; detects sensations such as touch, pain, warmth, and cold; stores fat and provides insulation.



SKELETAL SYSTEM (CHAPTERS 6–9)

Components: **Bones** and **joints** of the body and their associated **cartilages.**

Functions: Supports and protects body; provides surface area for muscle attachments; aids body movements; houses cells that produce blood cells; stores minerals and lipids (fats).



that all body systems influence one another. As you study each of the body systems in more detail, you will discover how they work together to maintain health, provide protection from disease, and allow for reproduction of the human species.

CLINICAL CONNECTION | *Noninvasive diagnostic techniques*

Health-care professionals and students of anatomy and physiology commonly use several noninvasive diagnostic techniques to assess certain aspects of body structure and function. A noninvasive diagnostic technique is one that does not involve insertion of an instrument or device through the skin or a body opening. In inspection, the examiner observes the body for any changes that deviate from normal. For example, a physician may examine the mouth cavity for evidence of disease. Following inspection, one or more additional techniques may be employed. In palpation (pal-PĀ-shun; *palp-* = gently touching) the examiner feels body surfaces with the hands. An example is palpating the abdomen to detect enlarged or tender internal organs or abnormal masses. In auscultation (aws-kul-TĀ-shun; *auscult-* = listening) the examiner listens to body sounds to evaluate the functioning of certain organs, often using a stethoscope to amplify the sounds. An example is auscultation of the lungs during breathing to check for crackling sounds associated with abnormal fluid accumulation. In percussion (pur-KUSH-un; *percus-* = beat through) the examiner taps on the body surface with the fingertips and listens to the resulting sound. Hollow cavities or spaces produce a different sound than solid organs. For example, percussion may reveal the abnormal presence of fluid in the lungs or air in the intestines. It may also provide information about the size, consistency, and position of an underlying structure. An understanding of anatomy is important for the effective application of most of these diagnostic techniques. •

CHECKPOINT

3. Define the following terms: atom, molecule, cell, tissue, organ, system, and organism.
4. At what levels of organisation would an exercise physiologist study the human body? (*Hint: refer to table 1.1.*)
5. Referring to table 1.2, which body systems help eliminate wastes?

1.3 Characteristics of the living human organism

OBJECTIVE

- Define the important life processes of the human body.

Basic life processes

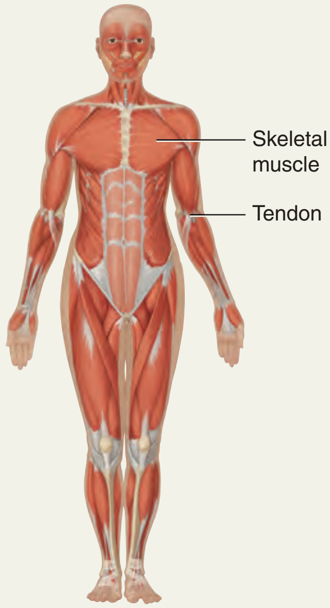
Certain processes distinguish organisms, or living things, from nonliving things. Following are the six most important life processes of the human body.

1. **Metabolism** (me-TAB-ō-lizm) is the sum of all chemical processes that occur in the body. One phase of metabolism is **catabolism** (ka-TAB-ō-lizm; *catabol-* = throwing down; *-ism* = a condition), the breakdown of complex chemical substances into simpler components. The other phase of metabolism is **anabolism** (a-NAB-ō-lizm; *anabol-* = a raising up), the building up of complex chemical substances from smaller, simpler components. For example, digestive processes catabolise (split)

MUSCULAR SYSTEM (CHAPTERS 10, 11)

Components: Specifically, **skeletal muscle** tissue — muscle usually attached to bones (other muscle tissues include smooth and cardiac).

Functions: Participates in body movements, such as walking; maintains posture; produces heat.



NERVOUS SYSTEM (CHAPTERS 12–17)

Components: **Brain, spinal cord, nerves,** and special sense organs, such as **eyes** and **ears.**

Functions: Generates action potentials (nerve impulses) to regulate body activities; detects changes in body's internal and external environments, interprets changes, and responds by causing muscular contractions or glandular secretions.

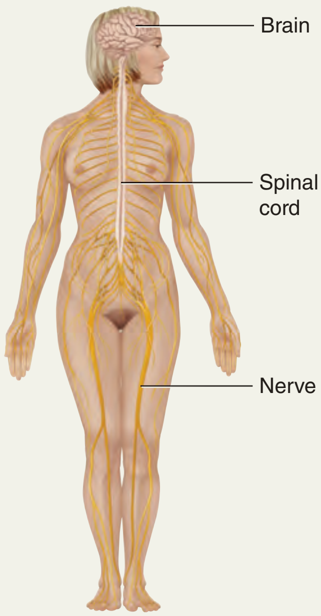


TABLE 1.2 CONTINUES

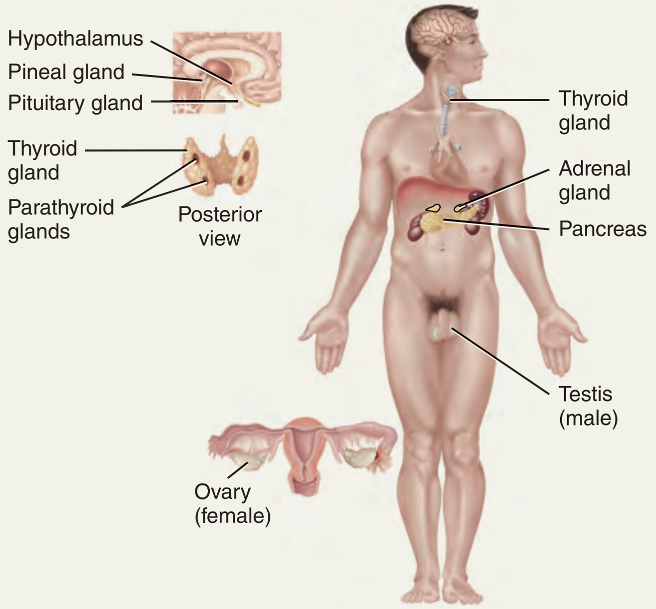
TABLE 1.2 CONTINUED

The eleven systems of the human body

ENDOCRINE SYSTEM (CHAPTER 18)

Components: Hormone-producing glands (**pineal gland, hypothalamus, pituitary gland, thymus, thyroid gland, parathyroid glands, adrenal glands, pancreas, ovaries,** and **testes)** and hormone-producing cells in several other organs.

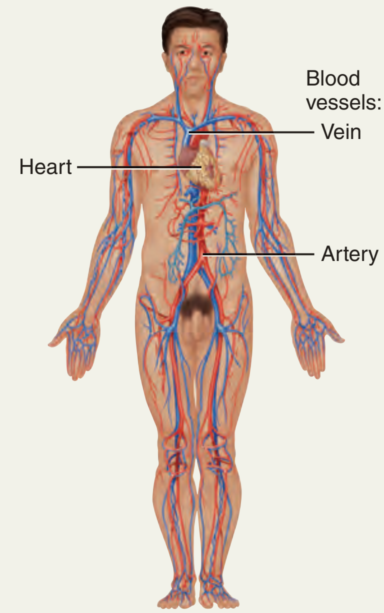
Functions: Regulates body activities by releasing hormones (chemical messengers transported in blood from endocrine gland or tissue to target organ).



CARDIOVASCULAR SYSTEM (CHAPTERS 19–21)

Components: **Blood, heart,** and **blood vessels.**

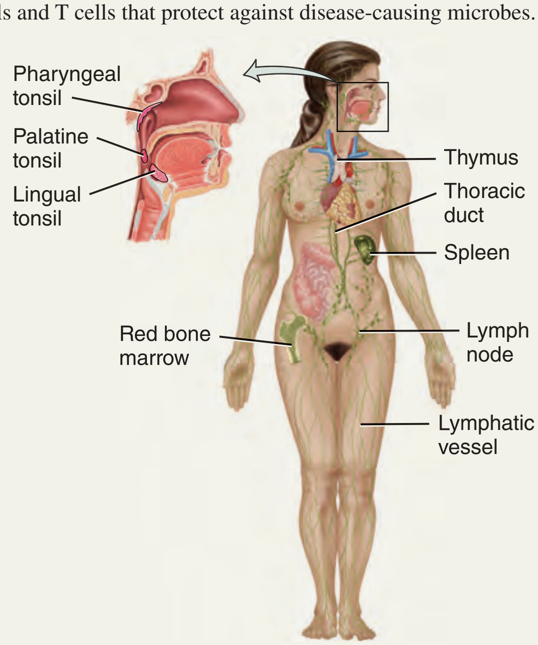
Functions: Heart pumps blood through blood vessels; blood carries oxygen and nutrients to cells and carbon dioxide and wastes away from cells and helps regulate acid–base balance, temperature, and water content of body fluids; blood components help defend against disease and repair damaged blood vessels.



LYMPHATIC SYSTEM AND IMMUNITY (CHAPTER 22)

Components: **Lymphatic fluid** and **vessels; spleen, thymus, lymph nodes,** and **tonsils;** cells that carry out immune responses (**B cells, T cells,** and others).

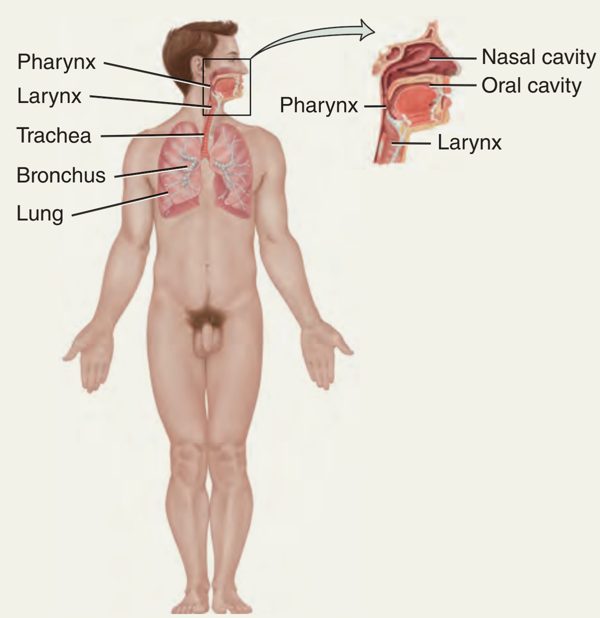
Functions: Returns proteins and fluid to blood; carries lipids from gastrointestinal tract to blood; contains sites of maturation and proliferation of B cells and T cells that protect against disease-causing microbes.



RESPIRATORY SYSTEM (CHAPTER 23)

Components: **Lungs** and air passageways such as the **pharynx** (throat), **larynx** (voice box), **trachea** (windpipe), and **bronchial tubes** leading into and out of lungs.

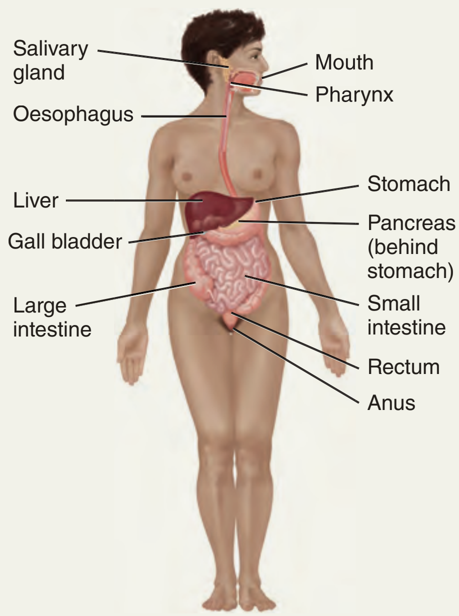
Functions: Transfers oxygen from inhaled air to blood and carbon dioxide from blood to exhaled air; helps regulate acid–base balance of body fluids; air flowing out of lungs through vocal cords produces sounds.



DIGESTIVE SYSTEM (CHAPTER 24)

Components: Organs of gastrointestinal tract, a long tube that includes the **mouth, pharynx** (throat), **oesophagus** (food tube), **stomach, small** and **large intestines,** and **anus;** also includes accessory organs that assist in digestive processes, such as **salivary glands, liver, gall bladder,** and **pancreas.**

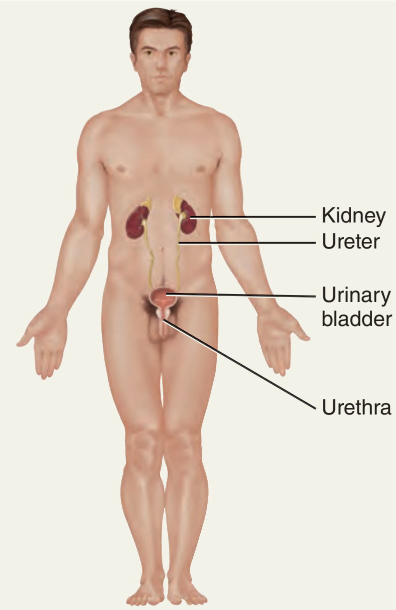
Functions: Achieves physical and chemical breakdown of food; absorbs nutrients; eliminates solid wastes.



URINARY SYSTEM (CHAPTER 26)

Components: **Kidneys, ureters, urinary bladder,** and **urethra.**

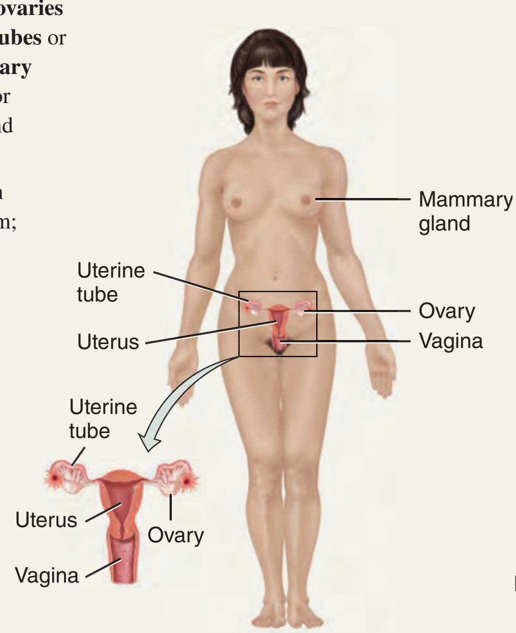
Functions: Produces, stores, and eliminates urine; eliminates wastes and regulates volume and chemical composition of blood; helps maintain the acid–base balance of body fluids; maintains body's mineral balance; helps regulate production of red blood cells.

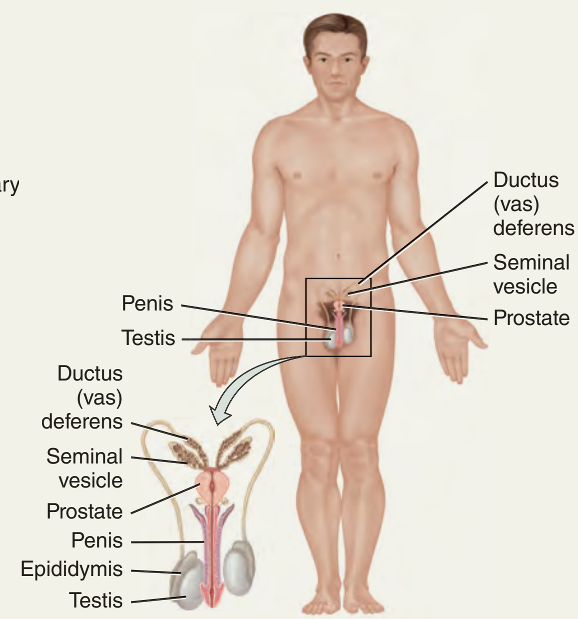


REPRODUCTIVE SYSTEMS (CHAPTER 28)

Components: **Gonads** (**testes** in males and **ovaries** in females) and associated organs (**uterine tubes** or *fallopian tubes*, **uterus, vagina,** and **mammary glands** in females and **epididymis, ductus** or **vas deferens, seminal vesicles, prostate,** and **penis** in males).

Functions: Gonads produce gametes (sperm or oocytes) that unite to form a new organism; gonads also release hormones that regulate reproduction and other body processes; associated organs transport and store gametes; mammary glands produce milk.





proteins in food into amino acids. These amino acids are then used to anabolise (build) new proteins that make up body structures such as muscles and bones.

2. **Responsiveness** is the body's ability to detect and respond to changes. For example, an increase in body temperature during a fever represents a change in the internal environment (within the body), and turning your head towards the sound of squealing brakes is a response to a change in the external environment (outside the body) to prepare the body for a potential threat. Different cells in the body respond to environmental changes in characteristic ways. Nerve cells respond by generating electrical signals known as nerve impulses (action potentials). Muscle cells respond by contracting, which generates force to move body parts.

3. **Movement** includes motion of the whole body, individual organs, single cells, and even tiny structures inside cells. For

example, the coordinated action of leg muscles moves your whole body from one place to another when you walk or run. After you eat a meal that contains fats, your gall bladder contracts and releases bile into the gastrointestinal tract to help digest them. When a body tissue is damaged or infected, certain white blood cells move from the bloodstream into the affected tissue to help clean up and repair the area. Inside the cell, various parts, such as secretory vesicles (see figure 3.20), move from one position to another to carry out their functions.

4. **Growth** is an increase in body size that results from an increase in the size of existing cells, an increase in the number of cells, or both. In addition, a tissue sometimes increases in size because the amount of material between cells increases. In a growing bone, for example, mineral deposits accumulate between bone cells, causing the bone to grow in length and width.
5. **Differentiation** (dif′-er-en-shē-Ā-shun) is the development of a cell from an unspecialised to a specialised state. Such precursor cells, which can divide and give rise to cells that undergo differentiation, are known as **stem cells.** As you will see later in the text, each type of cell in the body has a specialised structure or function that differs from that of its precursor (ancestor) cells. For example, red blood cells and several types of white blood cells all arise from the same unspecialised precursor cells in red bone marrow. Also through differentiation, a single fertilised human egg (ovum) develops into an embryo, and then into a foetus, an infant, a child, and finally an adult.
6. **Reproduction** (rē-prō-DUK-shun) refers either to (1) the formation of new cells for tissue growth, repair, or replacement, or (2) the production of a new individual. The formation of new cells occurs through cell division. The production of a new individual occurs through the fertilisation of an ovum by a sperm cell to form a zygote, followed by repeated cell divisions and the differentiation of these cells.

When any one of the life processes ceases to occur properly, the result is death of cells and tissues, which may lead to death of the organism. Clinically, loss of the heartbeat, absence of spontaneous breathing, and loss of brain functions indicate death in the human body.

CLINICAL CONNECTION | *Autopsy*

An autopsy (AW-top-sē = seeing with one's own eyes) or *necropsy* is a postmortem (after death) examination of the body and dissection of its internal organs to confirm or determine the cause of death. An autopsy can uncover the existence of diseases not detected during life, determine the extent of injuries, and explain how those injuries may have contributed to a person's death. It also may provide more information about a disease, assist in the accumulation of statistical data, and educate health-care students. Moreover, an autopsy can reveal conditions that may affect offspring or siblings (such as congenital heart defects). Sometimes an autopsy is legally required, such as during a criminal investigation. It may also be useful in resolving disputes between beneficiaries and insurance companies about the cause of death. •

CHECKPOINT

6. List the six most important life processes in the human body.

1.4 Homeostasis

OBJECTIVES

- Define homeostasis.
- Describe the components of a feedback system.
- Contrast the operation of negative and positive feedback systems.
- Explain how homeostatic imbalances are related to disorders.

Homeostasis (hō′-mē-ō-STĀ-sis; *homeo-* = sameness; *-stasis* = standing still) is the condition of equilibrium (balance) in the body's internal environment due to the constant interaction of the body's many regulatory processes. Homeostasis is a dynamic condition. In response to changing conditions, the body's equilibrium can shift among points in a narrow range that is compatible with maintaining life. For example, the level of glucose in blood normally stays between 70 and 110 milligrams of glucose per 100 millilitres of blood.* Each structure, from the cellular level to the system level, contributes in some way to keeping the internal environment of the body within normal limits.

Homeostasis and body fluids

An important aspect of homeostasis is maintaining the volume and composition of **body fluids**, dilute, watery solutions containing dissolved chemicals that are found inside cells as well as surrounding them. The fluid within cells is **intracellular fluid** (*intra-* = inside), abbreviated **ICF.** The fluid outside body cells is **extracellular fluid (ECF)** (*extra-* = outside). The ECF that fills the narrow spaces between cells of tissues is known as **interstitial fluid** (in′-ter-STISH-al; *inter-* = between). As you progress with your studies, you will learn that the ECF differs depending on where it occurs in the body: ECF within blood vessels is termed **blood plasma**, within lymphatic vessels it is called **lymph**, in and around the brain and spinal cord it is known as **cerebrospinal fluid**, in joints it is referred to as **synovial fluid**, and the ECF of the eyes is called **aqueous humour** and **vitreous body.**

The proper functioning of body cells depends on precise regulation of the composition of the interstitial fluid surrounding them. Because of this, interstitial fluid is often called the body's *internal environment.* The composition of interstitial fluid changes as substances move back and forth between it and blood plasma. Such exchange of materials occurs across the thin walls of the smallest blood vessels in the body, the *blood capillaries.* This movement in both directions across capillary walls provides needed materials, such as glucose, oxygen, ions, and so on, to tissue cells. It also removes wastes, such as carbon dioxide, from interstitial fluid.

*Appendix A describes metric and imperial measurements.

Control of homeostasis

Homeostasis in the human body is continually being disturbed. Some disruptions come from the external environment in the form of physical insults such as the intense heat of a hot summer day or a lack of enough oxygen for that two-mile run. Other disruptions originate in the internal environment, such as a blood glucose level that falls too low when you skip breakfast. Homeostatic imbalances may also occur due to psychological stresses in our social environment — the demands of work and school, for example. In most cases the disruption of homeostasis is mild and temporary, and the responses of body cells quickly restore balance in the internal environment. However, in some cases the disruption of homeostasis may be intense and prolonged, as in poisoning, overexposure to temperature extremes, severe infection, or major surgery.

Fortunately, the body has many regulating systems that can usually bring the internal environment back into balance. Most often, the nervous system and the endocrine system, working together or independently, provide the needed corrective measures. The nervous system regulates homeostasis by sending electrical signals known as *nerve impulses (action potentials)* to organs that can counteract changes from the balanced state. The endocrine system includes many glands that secrete messenger molecules called *hormones* into the blood. Nerve impulses typically cause rapid changes, but hormones usually work more slowly. Both means of regulation, however, work towards the same end, usually through negative feedback systems.

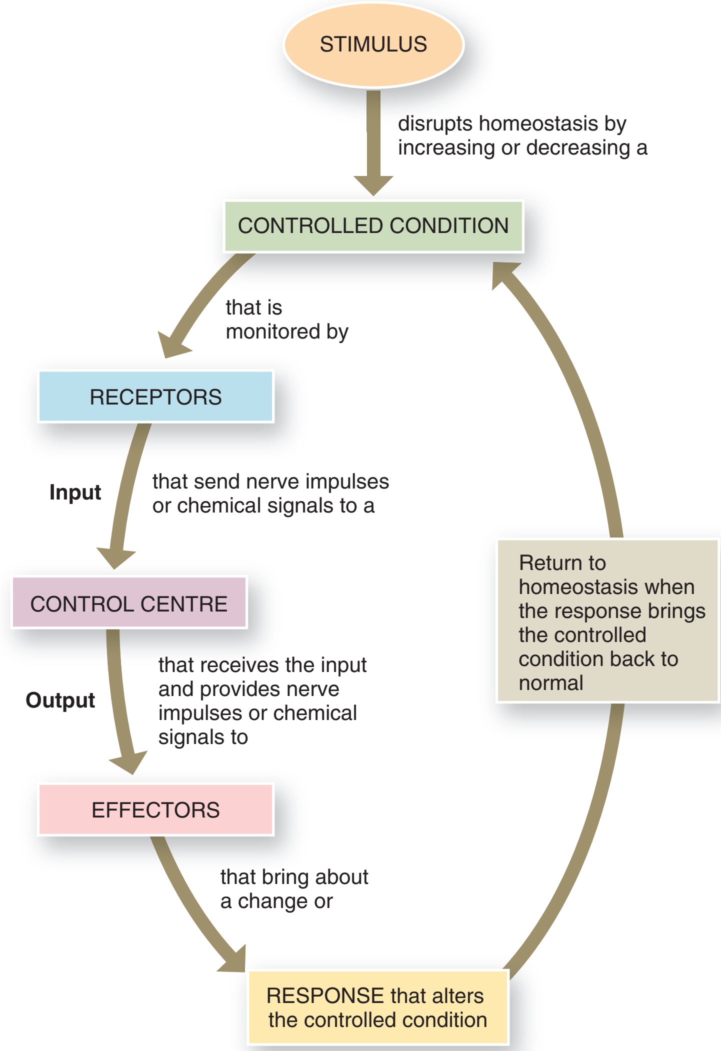
Feedback systems

The body can regulate its internal environment through many feedback systems. A **feedback system** or *feedback loop* is a cycle of events in which the status of a body condition is monitored, evaluated, changed, remonitored, reevaluated, and so on. Each monitored variable, such as body temperature, blood pressure, or blood glucose level, is termed a *controlled condition*. Any disruption that changes a controlled condition is called a *stimulus*. A feedback system includes three basic components: a receptor, a control centre, and an effector (figure 1.2).

1. A **receptor** is a body structure that monitors changes in a controlled condition and sends input to a control centre. This pathway is called an *afferent pathway* (AF-er-ent; *af-* = towards; *-ferrent* = carried), since the information flows *towards* the control centre. Typically, the *input* is in the form of nerve impulses or chemical signals. For example, certain nerve endings in the skin sense temperature and can detect changes, such as a dramatic drop in temperature.
2. A **control centre** in the body, for example, the brain, sets the range of values within which a controlled condition should be maintained (set point), evaluates the input it receives from receptors, and generates output commands when they are needed. *Output* from the control centre typically occurs as nerve impulses, or hormones or other chemical signals. This pathway is called an *efferent pathway* (EF-er-ent; *ef-* = away from), since the information flows *away from* the control centre. In our skin temperature example, the brain acts as the control centre, receiving nerve impulses from the skin receptors and generating nerve impulses as output.
3. An **effector** (e-FEK-tor) is a body structure that receives output from the control centre and produces a **response** or effect that changes the controlled condition. Nearly every organ or tissue in the body can behave as an effector. When your body temperature drops sharply, your brain (control centre) sends nerve impulses (output) to your skeletal muscles (effectors). The result is shivering, which generates heat and raises your body temperature.

Figure 1.2 **Operation of a feedback system.**

The three basic components of a feedback system are the receptor, control centre, and effector.



What is the main difference between negative and positive feedback systems?

A group of receptors and effectors communicating with their control centre forms a feedback system that can regulate a controlled condition in the body's internal environment. In a feedback system, the response of the system 'feeds back' information to change the controlled condition in some way, either negating it (negative feedback) or enhancing it (positive feedback).

Negative feedback systems A **negative feedback system** *reverses* a change in a controlled condition. Consider the regulation of blood pressure. Blood pressure (BP) is the force exerted by blood as it presses against the walls of blood vessels. When the heart beats faster or harder, BP increases. If some internal or external stimulus causes blood pressure (controlled condition) to rise, the following sequence of events occurs (figure 1.3). *Baroreceptors* (the receptors), pressure-sensitive nerve cells located in the walls of certain blood vessels, detect the higher pressure. The baroreceptors send nerve impulses (input) to the brain (control centre), which interprets the impulses and responds by sending nerve impulses (output) to the heart and blood vessels (the effectors). Heart rate decreases and blood vessels dilate (widen), which cause BP to decrease (response). This sequence of events quickly returns the controlled condition — blood pressure — to normal, and homeostasis is restored. Notice that the activity of the effector causes BP to drop, a result that negates the original stimulus (an increase in BP). This is why it is called a negative feedback system.

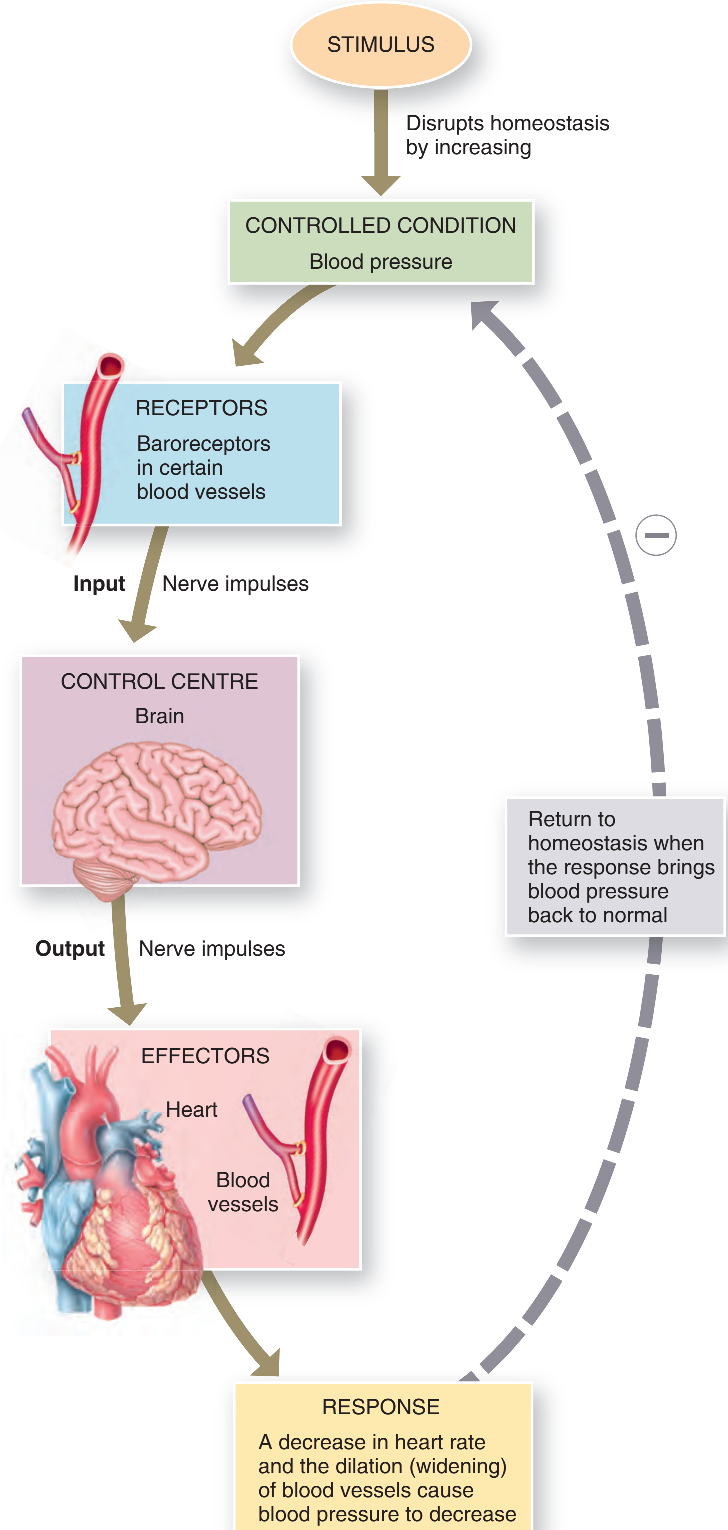
Positive feedback systems Unlike a negative feedback system, a **positive feedback system** tends to *strengthen* or *reinforce* a change in one of the body's controlled conditions. In a positive feedback system, the response affects the controlled condition differently than in a negative feedback system. The control centre still provides commands to an effector, but this time the effector produces a physiological response that adds to or *reinforces* the initial change in the controlled condition. The action of a positive feedback system continues until it is interrupted by some mechanism.

Normal childbirth provides a good example of a positive feedback system (figure 1.4). The first contractions of labour (stimulus) push part of the foetus into the cervix, the lowest part of the uterus, which opens into the vagina. Stretch-sensitive nerve cells (receptors) monitor the amount of stretching of the cervix (controlled condition). As stretching increases, they send more nerve impulses (input) to the brain (control centre), which in turn releases the hormone oxytocin (output) into the blood. Oxytocin causes muscles in the wall of the uterus (effector) to contract even more forcefully. The contractions push the foetus farther down the uterus, which stretches the cervix even more. The cycle of stretching, hormone release, and ever-stronger contractions is interrupted only by the birth of the baby. Then, stretching of the cervix ceases and oxytocin is no longer released.

Another example of positive feedback is what happens to your body when you lose a great deal of blood. Under normal conditions, the heart pumps blood under sufficient pressure to body cells to provide them with oxygen and nutrients to maintain homeostasis. Upon severe blood loss, blood pressure drops and blood cells (including heart cells) receive less oxygen and function less efficiently. If the blood loss continues, heart cells become weaker, the pumping action of the heart decreases further, and blood pressure continues to fall. This is an example of a positive feedback cycle that has serious consequences and

Figure 1.3 **Homeostatic regulation of blood pressure by a negative feedback system.** The broken return arrow with a negative sign surrounded by a circle symbolises negative feedback.

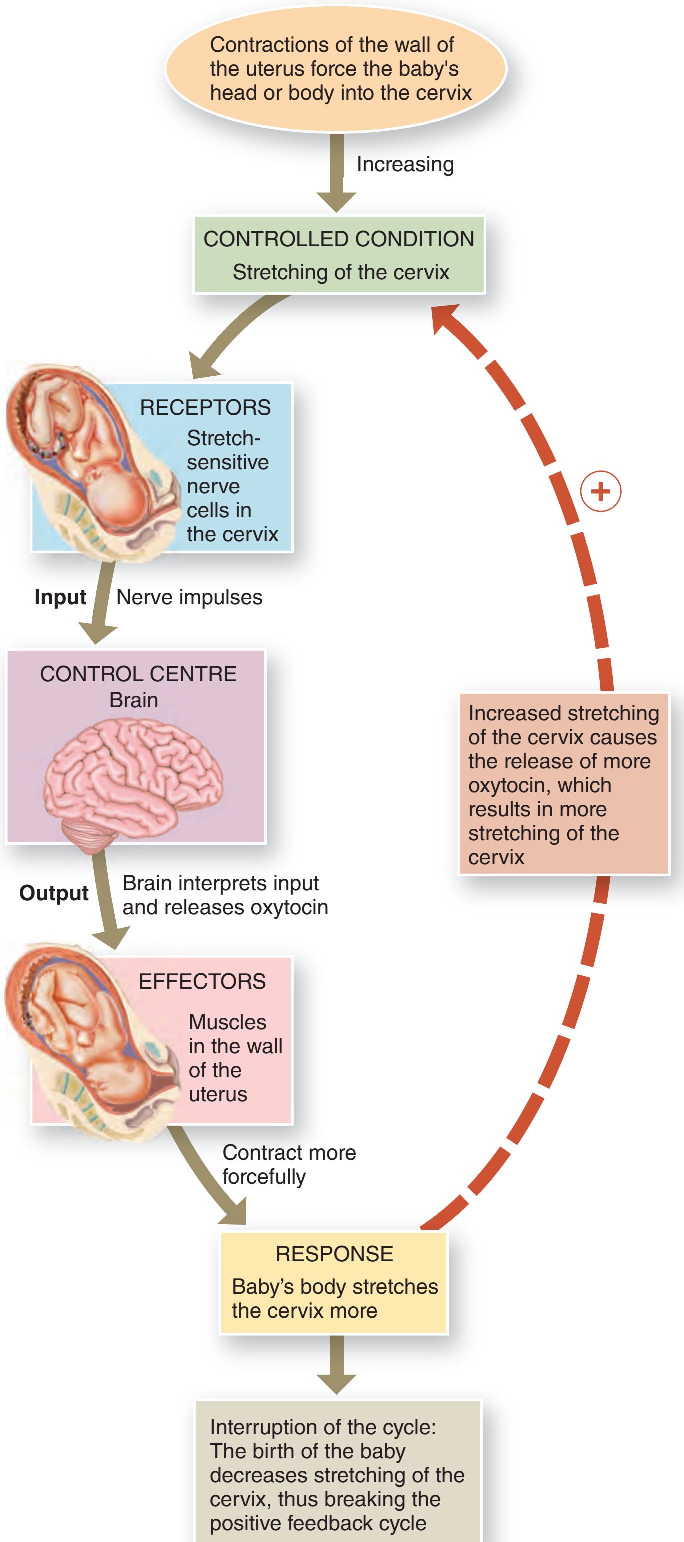
If the response reverses the stimulus, a system is operating by negative feedback.



What would happen to heart rate if some stimulus caused blood pressure to decrease? Would this occur by way of positive or negative feedback?

Figure 1.4 Positive feedback control of labour contractions during birth of a baby. The broken return arrow with a positive sign surrounded by a circle symbolises positive feedback.

If the response enhances or intensifies the stimulus, a system is operating by positive feedback.



Why do positive feedback systems that are part of a normal physiological response include some mechanism that terminates the system?

may even lead to death if there is no medical intervention. As you will see in chapter 19, blood clotting is also an example of a positive feedback system.

These examples suggest some important differences between positive and negative feedback systems. Because a positive feedback system continually reinforces a change in a controlled condition, some event outside the system must shut it off. If the action of a positive feedback system is not stopped, it can 'run away' and may even produce life-threatening conditions in the body. The action of a negative feedback system, by contrast, slows and then stops as the controlled condition returns to its normal state. Usually, positive feedback systems reinforce conditions that do not happen very often, and negative feedback systems regulate conditions in the body that remain fairly stable over long periods.

Homeostatic imbalances

You've seen homeostasis defined as a condition in which the body's internal environment remains relatively stable. The body's ability to maintain homeostasis gives it tremendous healing power and a remarkable resistance to abuse. The physiological processes responsible for maintaining homeostasis are in large part also responsible for your good health.

For most people, lifelong good health is not something that happens effortlessly. The many factors in this balance called health include the following:

- the environment and your own behaviour
- your genetic makeup
- the air you breathe, the food you eat, and even the thoughts you think.

The way you live your life can either support or interfere with your body's ability to maintain homeostasis and recover from the inevitable stresses life throws your way.

Many diseases are the result of years of poor health behaviour that interferes with the body's natural drive to maintain homeostasis. An obvious example is smoking-related illness. Smoking tobacco exposes sensitive lung tissue to a multitude of chemicals that cause cancer and damage the lung's ability to repair itself. Because diseases such as emphysema and lung cancer are difficult to treat and are very rarely cured, it is much wiser to quit smoking — or never start — than to hope a doctor can 'fix' you once you are diagnosed with a lung disease. Developing a lifestyle that works with, rather than against, your body's homeostatic processes helps you maximise your personal potential for optimal health and well being.

As long as all of the body's controlled conditions remain within certain narrow limits, body cells function efficiently, homeostasis is maintained, and the body stays healthy. Should one or more components of the body lose their ability to contribute to homeostasis, however, the normal balance among all of the body's processes may be disturbed. If the homeostatic imbalance is moderate, a disorder or disease may occur; if it is severe, death may result.

A **disorder** is any abnormality of structure or function. **Disease** is a more specific term for an illness characterised by a recognisable set of signs and symptoms. A *local disease* affects one part or a limited region of the body (for example, a sinus infection); a *systemic disease* affects either the entire body or several parts of it (for example, influenza). Diseases alter body structures and functions in characteristic ways. A person with a disease may experience **symptoms**, *subjective* changes in body functions that are not apparent to an observer. Examples of symptoms are headache, nausea, and anxiety. *Objective* changes that a clinician can observe and measure are called **signs.** Signs of disease can be either anatomical, such as swelling or a rash, or physiological, such as fever, high blood pressure, or paralysis.

The science that deals with why, when, and where diseases occur and how they are transmitted among individuals in a community is known as **epidemiology** (ep′-i-dē-mē-OL-ō-jē; *epi-* = upon; *-demi* = people). **Pharmacology** (far′-ma-KOL-ō-jē; *pharmac-* = drug) is the science that deals with the effects and uses of drugs in the treatment of disease.

CLINICAL CONNECTION | *Diagnosis of disease*

Diagnosis (dī-ag-NŌ-sis; *dia-* = through; *-gnosis* = knowledge) is the science and skill of distinguishing one disorder or disease from another. The patient's symptoms and signs, his or her medical history, a physical exam, and laboratory tests provide the basis for making a diagnosis. Taking a *medical history* consists of collecting information about events that might be related to a patient's illness. These include the chief complaint (primary reason for seeking medical attention), history of present illness, past medical problems, family medical problems, social history, and review of symptoms. A *physical examination* is an orderly evaluation of the body and its functions. This process includes the noninvasive techniques of inspection, palpation, auscultation, and percussion that you learned about earlier in the chapter, along with measurement of vital signs (temperature, pulse, respiratory rate, and blood pressure), and sometimes laboratory tests. •

CHECKPOINT

7. Describe the locations of intracellular fluid, extracellular fluid, interstitial fluid, and blood plasma.
8. Why is interstitial fluid called the internal environment of the body?
9. What types of disturbances can act as stimuli that initiate a feedback system?
10. Define receptor, control centre, and effector.
11. What is the difference between symptoms and signs of a disease? Give examples of each.

1.5 Basic anatomical terminology

OBJECTIVES

- Describe the anatomical position.
- Relate the anatomical names and the corresponding common names for various regions of the human body.
- Define the anatomical planes, anatomical sections, and directional terms used to describe the human body.
- Outline the major body cavities, the organs they contain, and their associated linings.

Scientists and health-care professionals use a common language of special terms when referring to body structures and their functions. The language of anatomy they use has precisely defined meanings that allow us to communicate clearly and precisely. For example, is it correct to say, 'The wrist is above the fingers'? This might be true if your upper limbs (described shortly) are at your sides. But if you hold your hands up above your head, your fingers would be above your wrists. To prevent this kind of confusion, anatomists use a standard anatomical position and a special vocabulary for relating body parts to one another.

Body positions

Descriptions of any region or part of the human body assume that it is in a standard position of reference called the **anatomical position** (an′-a-TOM-i-kal). In the anatomical position, the subject stands erect facing the observer, with the head level and the eyes facing directly forward. The lower limbs are parallel and the feet are flat on the floor and directed forward, and the upper limbs are at the sides with the palms turned forward (figure 1.5). Two terms describe a reclining body. If the body is lying facedown, it is in the **prone** position. If the body is lying faceup, it is in the **supine** position.

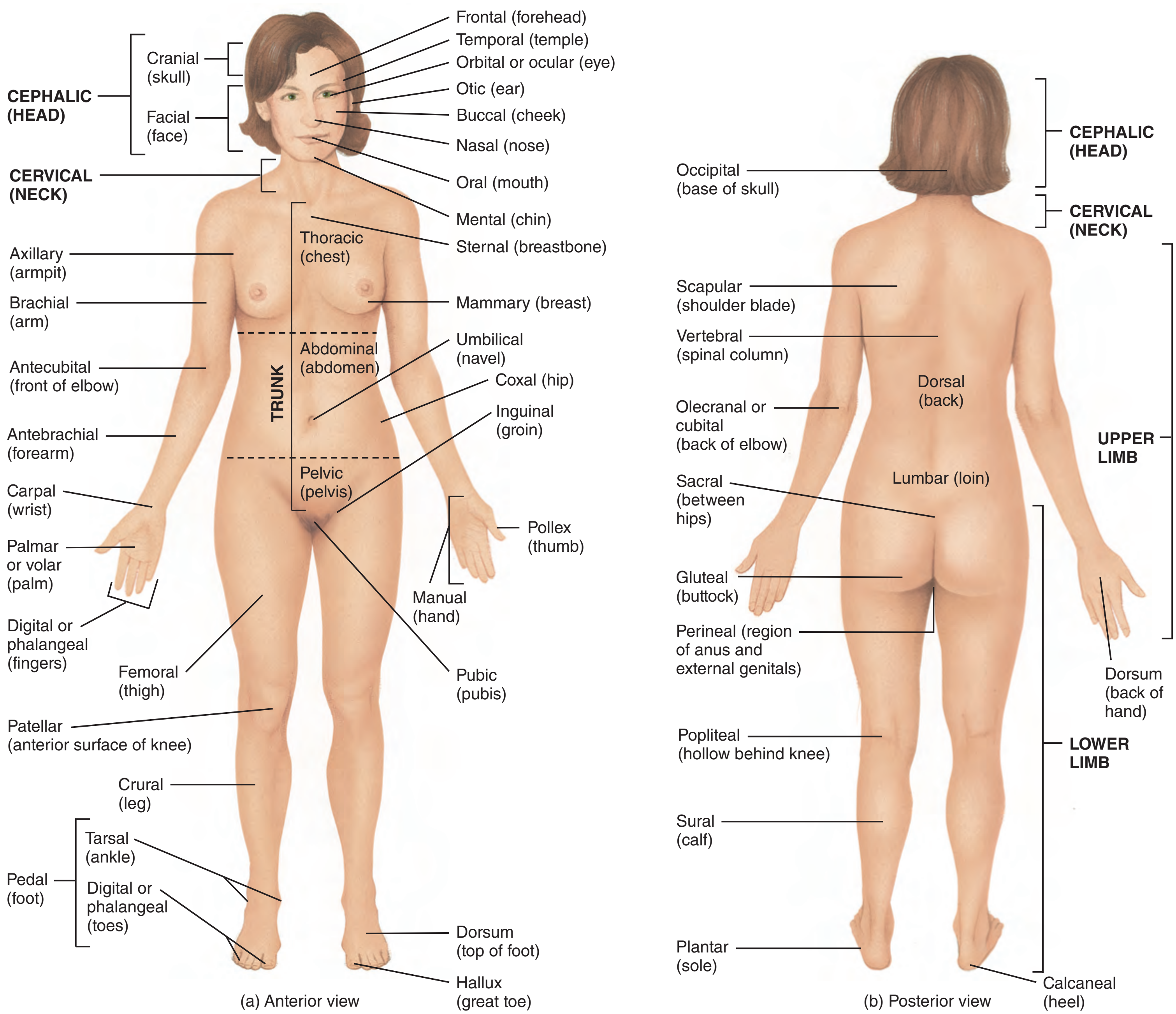
Regional names

The human body is divided into several major regions that can be identified externally. The principal regions are the head, neck, trunk, upper limbs, and lower limbs (figure 1.5). The **head** consists of the skull and face. The *skull* encloses and protects the brain; the *face* is the front portion of the head that includes the eyes, nose, mouth, forehead, cheeks, and chin. The **neck** supports the head and attaches it to the trunk. The **trunk** consists of the chest, abdomen, and pelvis. Each **upper limb** attaches to the trunk and consists of the shoulder, armpit, arm (portion of the limb from the shoulder to the elbow), forearm (portion of the limb from the elbow to the wrist), wrist, and hand. Each **lower limb** also attaches to the trunk and consists of the buttock, thigh (portion of the limb from the buttock to the knee), leg (portion of the limb from the knee to the ankle), ankle, and foot. The *groin* is the area on the front surface of the body marked by a crease on each side, where the trunk attaches to the thighs.

Figure 1.5 shows the anatomical and common names of major parts of the body. For example, if you receive a tetanus shot in your *gluteal region,* it is an injection in your *buttock*. Because the anatomical term for a body part usually is based on

Figure 1.5 **The anatomical position.** The anatomical names and corresponding common names (in parentheses) are indicated for specific body regions. For example, the cephalic region is the head.

In the anatomical position, the subject stands erect facing the observer with the head level and the eyes facing forward. The lower limbs are parallel and the feet are flat on the floor and directed forward, and the upper limbs are at the sides with the palms facing forward.



What is the usefulness of defining one standard anatomical position?

a Greek or Latin word, it may look different from the common name for the same part or area. For example, the Latin word *axilla* (ak-SIL-a) is the common name for armpit. Thus, the axillary nerve is one of the nerves passing within the armpit. You will learn more about the Greek and Latin word roots of anatomical and physiological terms as you read this book.

Directional terms

To locate various body structures, anatomists use specific **directional terms**, words that describe the position of one body part relative to another. Several directional terms are grouped in pairs that have opposite meanings, such as anterior (front) and posterior (back). Exhibit 1.A and figure 1.6 present the main directional terms.

EXHIBIT 1.A Directional terms *(figure 1.6)*

OBJECTIVE

- Define each directional term used to describe the human body.

OVERVIEW

Most of the directional terms used to describe the relationship of one part of the body to another can be grouped into pairs that have opposite meanings. For example, **superior** means towards the upper part of the body, and **inferior** means towards the lower part of the body. It is important to understand that directional terms have relative meanings; they make sense only when used to describe the position of one structure relative to another. For example, your knee is superior to your ankle, even though both are located in the inferior half of the body. Study the directional terms below and the example of how each is used. As you read the examples, look at figure 1.6 to see the location of each structure.

CHECKPOINT

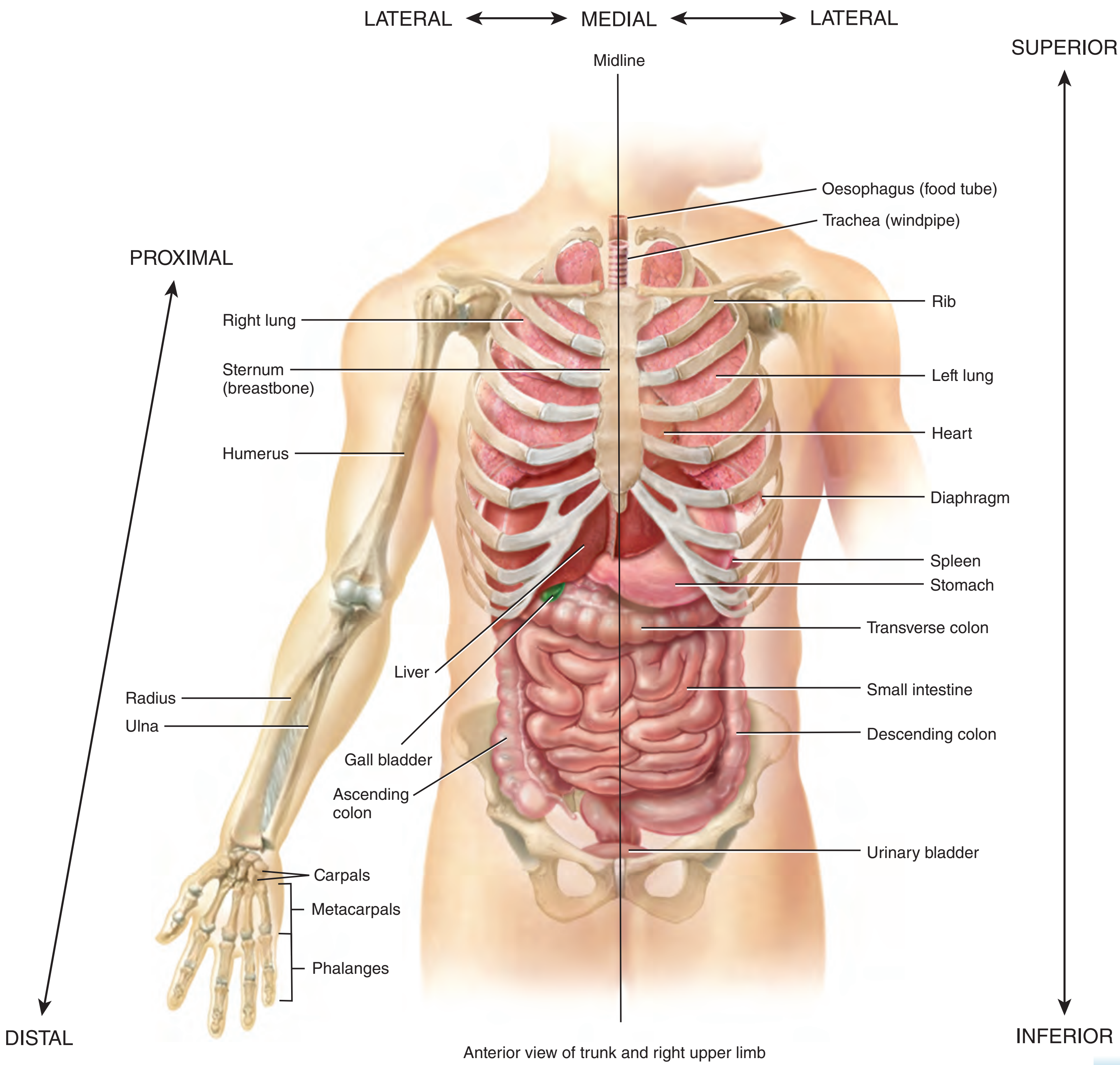
12. Which directional terms can be used to specify the relationships between (1) the elbow and the shoulder, (2) the left and right shoulders, (3) the sternum and the humerus, and (4) the heart and the diaphragm?

DIRECTIONAL TERM	DEFINITION	EXAMPLE OF USE
Superior (soo′-PĒR-ē-or) (**cephalic** or **cranial**)	Towards the head, or the upper part of a structure.	The heart is superior to the liver.
Inferior (in-FĒ-rē-or) (**caudal**)	Away from the head, or the lower part of a structure.	The stomach is inferior to the lungs.
Anterior (an-TĒR-ē-or) (**ventral**)*	Nearer to or at the front of the body.	The sternum (breastbone) is anterior to the heart.
Posterior (pos-TĒR-ē-or) (**dorsal**)	Nearer to or at the back of the body.	The oesophagus (food tube) is posterior to the trachea (windpipe).
Medial (MĒ-dē-al)	Nearer to the midline (an imaginary vertical line that divides the body into equal right and left sides).	The ulna is medial to the radius.
Lateral (LAT-er-al)	Farther from the midline.	The lungs are lateral to the heart.
Intermediate (in′-ter-MĒ-dē-at)	Between two structures.	The transverse colon is intermediate to the ascending and descending colons.
Ipsilateral (ip-si-LAT-er-al)	On the same side of the body as another structure.	The gall bladder and ascending colon are ipsilateral.
Contralateral (KON-tra-lat-er-al)	On the opposite side of the body from another structure.	The ascending and descending colons are contralateral.
Proximal (PROK-si-mal)	Nearer to the attachment of a limb to the trunk; nearer to the origination of a structure.	The humerus (arm bone) is proximal to the radius.
Distal (DIS-tal)	Farther from the attachment of a limb to the trunk; farther from the origination of a structure.	The phalanges (finger bones) are distal to the carpals (wrist bones).
Superficial (soo′-per-FISH-al) (**external**)	Towards or on the surface of the body.	The ribs are superficial to the lungs.
Deep (Internal)	Away from the surface of the body.	The ribs are deep to the skin of the chest and back.

*Note that the terms *anterior* and *ventral* mean the same thing in humans. However, in four-legged animals *ventral* refers to the belly side and is therefore *inferior.* Similarly, the terms *posterior* and *dorsal* mean the same thing in humans, but in four-legged animals *dorsal* refers to the back side and is therefore *superior.*

Figure 1.6 **Directional terms.**

Directional terms precisely locate various parts of the body relative to one another.



Anterior view of trunk and right upper limb

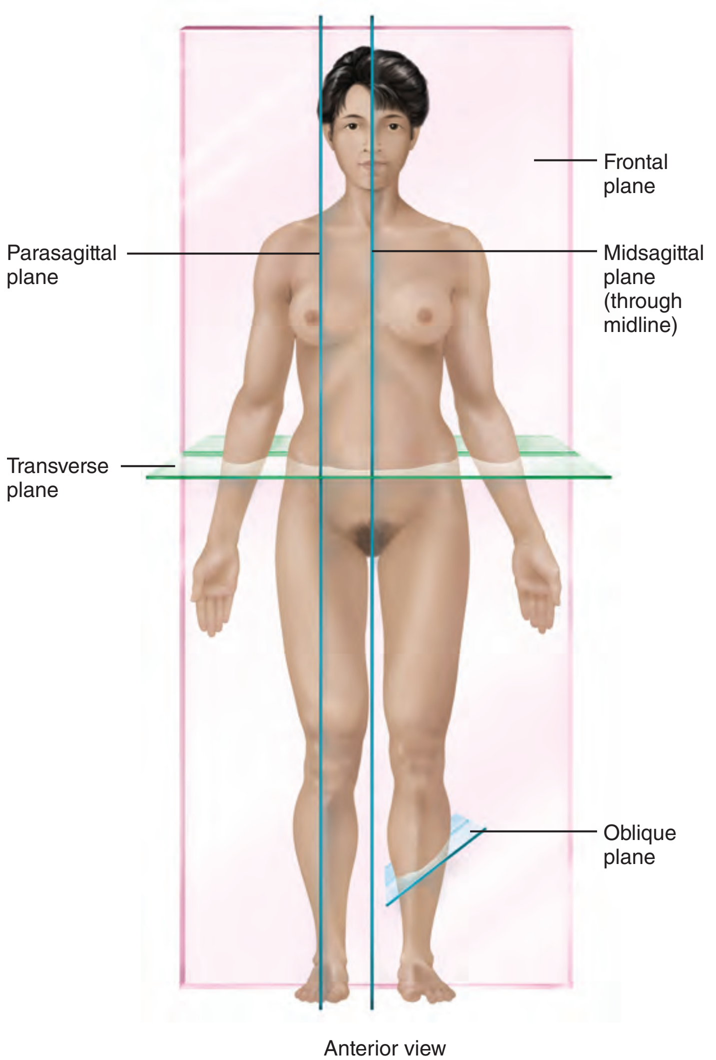
Is the radius proximal to the humerus? Is the oesophagus anterior to the trachea? Are the ribs superficial to the lungs? Is the urinary bladder medial to the ascending colon? Is the sternum lateral to the descending colon?

Planes and sections

You will also study parts of the body relative to **planes**, imaginary flat surfaces that pass through the body parts (figure 1.7). A **sagittal plane** (SAJ-i-tal; *sagitt-* = arrow) is a vertical plane that divides the body or an organ into right and left sides. More specifically, when such a plane passes through the midline of the body or an organ and divides it into *equal* right and left sides, it is called a **midsagittal plane** or a **median plane.** The **midline** is an imaginary vertical line that divides the body into equal left and right sides. If the sagittal plane does not pass through the midline but instead divides the body or an organ into *unequal* right and left sides, it is called a **parasagittal plane** (*para-* = near). A **frontal** or *coronal plane* (kō-RŌ-nal; *corona* = crown) divides the body or an organ into anterior (front) and posterior (back) portions. A **transverse plane** divides the body or an organ into superior (upper) and inferior (lower) portions. Other names for a transverse plane are a **cross-sectional** or **horizontal plane**. Sagittal, frontal, and transverse planes are all at right angles to one another. An **oblique plane** (ō-BLĒK), by contrast, passes through the body or an organ at an oblique angle (any angle other than a 90-degree angle).

Figure 1.7 Planes through the human body.

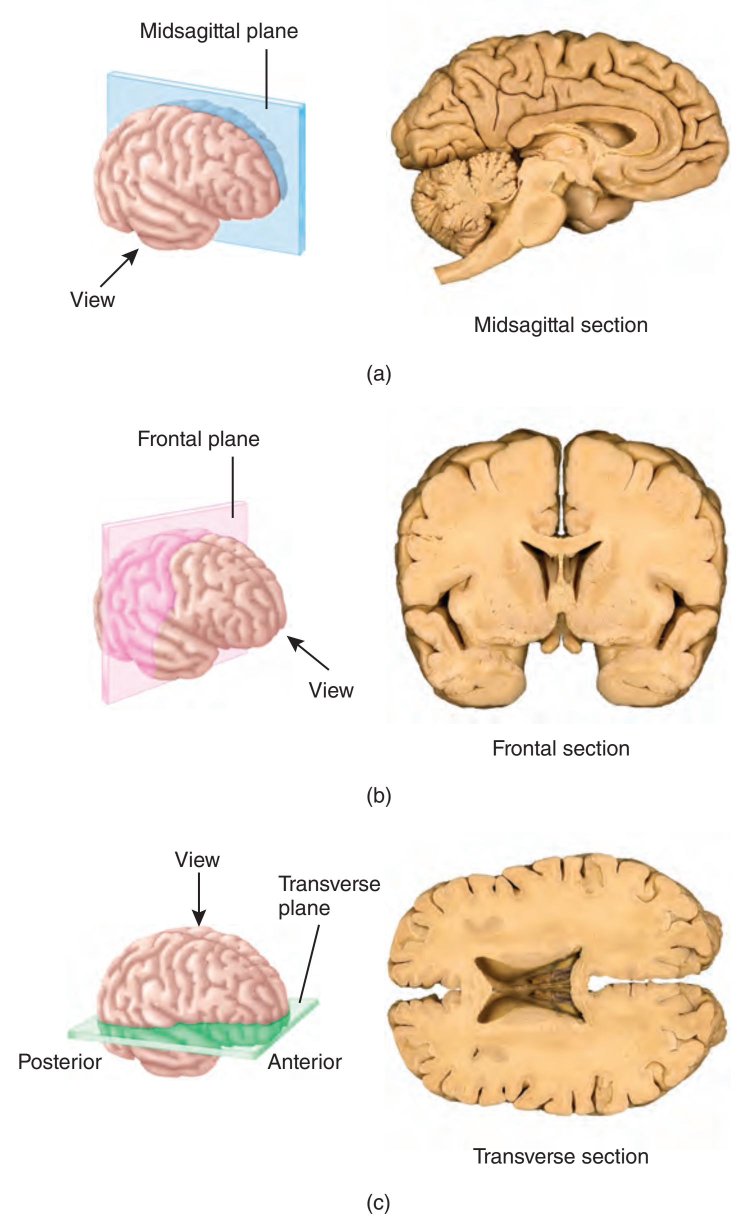
Frontal, transverse, sagittal, and oblique planes divide the body in specific ways.



Which plane divides the heart into anterior and posterior portions?

Figure 1.8 Planes and sections through different parts of the brain. The diagrams (left) show the planes, and the photographs (right) show the resulting sections. Note: the arrows in the diagrams indicate the direction from which each section is viewed. This aid is used throughout the book to indicate viewing perspectives.

Planes divide the body in various ways to produce sections.



Which plane divides the brain into unequal right and left portions?

When you study a body region, you often view it in section. A **section** is a cut of the body or one of its organs made along one of the planes just described. It is important to know the plane of the section so you can understand the anatomical relationship of one part to another. Figure 1.8a–c indicates how three different sections — *midsagittal*, *frontal*, and *transverse* — provide different views of the brain.

Body cavities

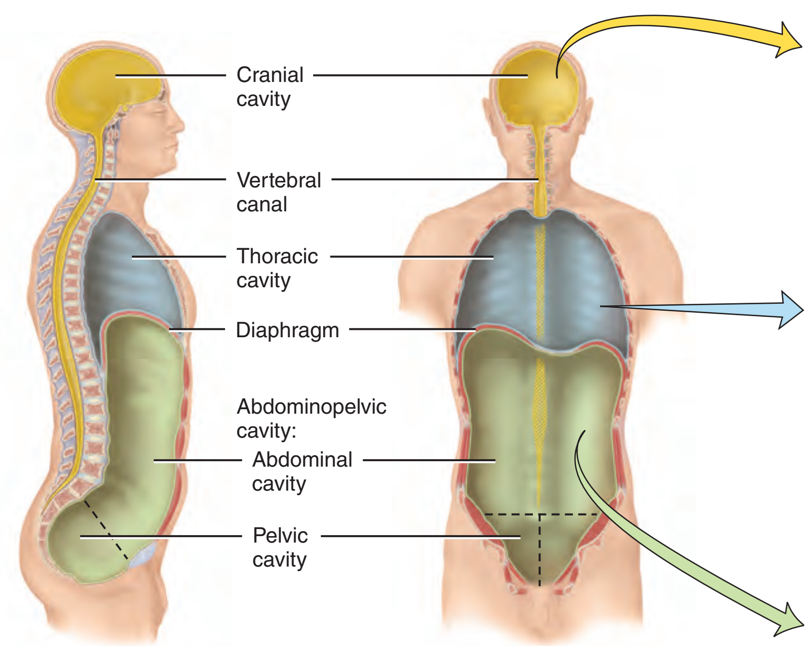
Body cavities are spaces that enclose internal organs. Bones, muscles, ligaments, and other structures separate the various body cavities from one another. Here we discuss several body cavities (figure 1.9).

The cranial bones form a hollow space of the head called the **cranial cavity** (KRĀ-nē-al), which contains the brain. The bones of the vertebral column (backbone) form the **vertebral (spinal) canal** (VER-te-bral), which contains the spinal cord. The cranial cavity and vertebral canal are continuous with one another. Three layers of protective tissue, the **meninges** (me-NIN-jēz), and a shock-absorbing fluid surround the brain and spinal cord.

The major body cavities of the trunk are the thoracic and abdominopelvic cavities. The **thoracic cavity** (thor-AS-ik; *thorac-* = chest) or chest cavity (figure 1.10) is formed by the ribs, the muscles of the chest, the sternum (breastbone), and the thoracic portion of the vertebral column. Within the thoracic cavity are the **pericardial cavity** (per′-i-KAR-dē-al; *peri-* = around; *-cardial* = heart), a fluid-filled space that surrounds the heart, and two fluid-filled spaces called **pleural cavities** (PLOOR-al; *pleur-* = rib or side), one around each lung. The central part of the thoracic cavity is an anatomical region called the **mediastinum** (mē′-dē-as-TĪ-num; *media-* = middle; *-stinum* = partition). It is between the lungs, extending from the sternum to the vertebral column and from the first rib to the diaphragm (figure 1.10a,b). The mediastinum contains all

Figure 1.9 **Body cavities.** The black dashed line in (a) indicates the border between the abdominal and pelvic cavities.

The major cavities of the trunk are the thoracic and abdominopelvic cavities.



(a) Right lateral view

(b) Anterior view

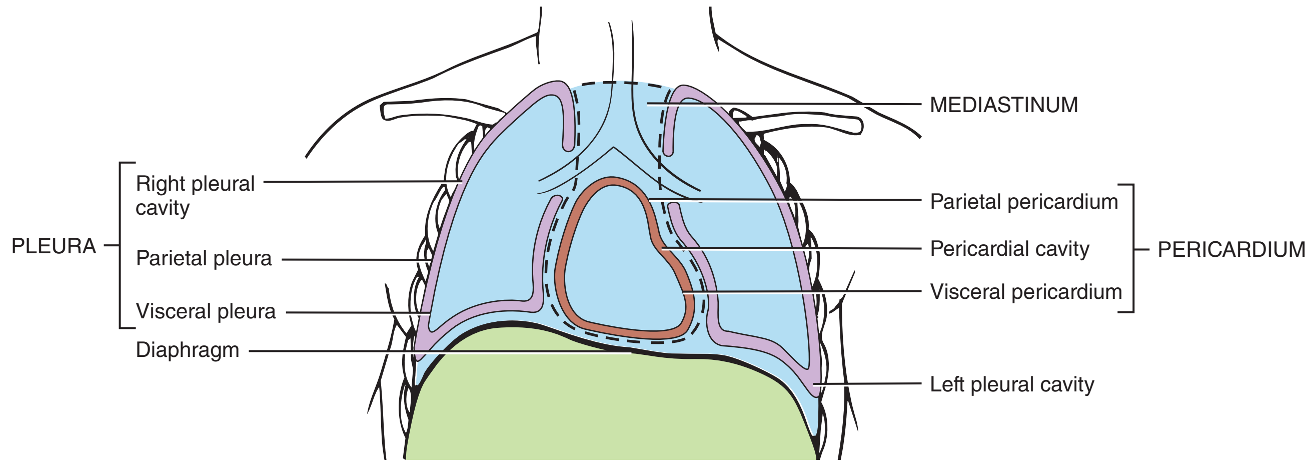
CAVITY	COMMENTS
Cranial cavity	Formed by cranial bones and contains brain.
Vertebral canal	Formed by vertebral column and contains spinal cord and the beginnings of spinal nerves.
Thoracic cavity*	Chest cavity; contains pleural and pericardial cavities and the mediastinum.
Pleural cavity	A potential space between the layers of the pleura that surrounds a lung.
Pericardial cavity	A potential space between the layers of the pericardium that surrounds the heart.
Mediastinum	Central portion of thoracic cavity between the lungs; extends from sternum to vertebral column and from first rib to diaphragm; contains heart, thymus, oesophagus, trachea, and several large blood vessels.
Abdominopelvic cavity	Subdivided into abdominal and pelvic cavities.
Abdominal cavity	Contains stomach, spleen, liver, gall bladder, small intestine, and most of large intestine; the serous membrane of the abdominal cavity is the peritoneum.
Pelvic cavity	Contains urinary bladder, portions of large intestine, and internal organs of reproduction.

* See figure 1.10 for details of the thoracic cavity.

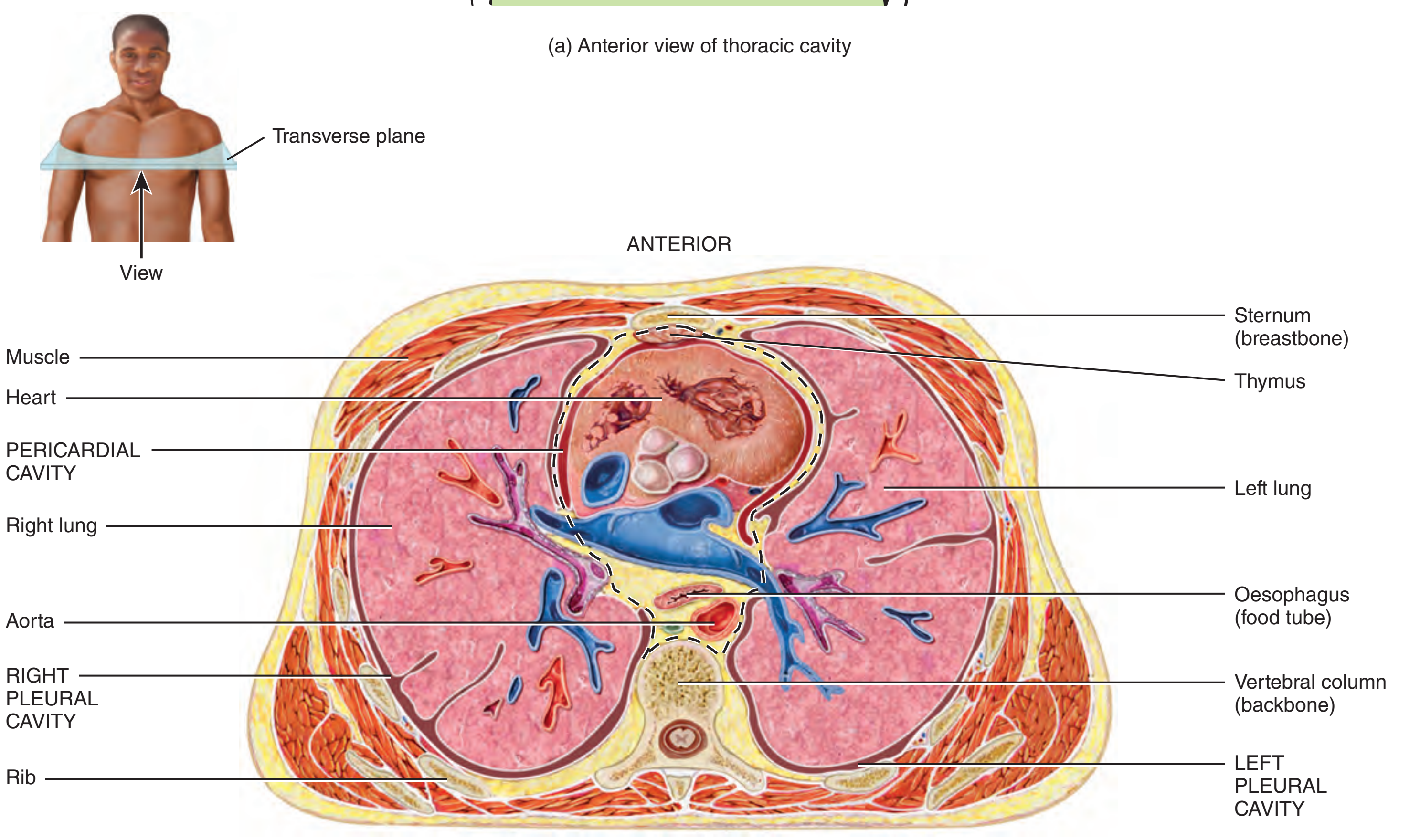
In which cavities are the following organs located: urinary bladder, stomach, heart, small intestine, lungs, internal female reproductive organs, thymus, spleen, liver? Use the following symbols for your responses: T = thoracic cavity, A = abdominal cavity, or P = pelvic cavity.

Figure 1.10 **The thoracic cavity.** The black dashed lines indicate the borders of the mediastinum. Note: when transverse sections are viewed inferiorly (from below), the anterior aspect of the body appears on top and the left side of the body appears on the right side of the illustration.

The thoracic cavity contains three smaller cavities and the mediastinum.



(a) Anterior view of thoracic cavity



(b) Inferior view of transverse section of thoracic cavity

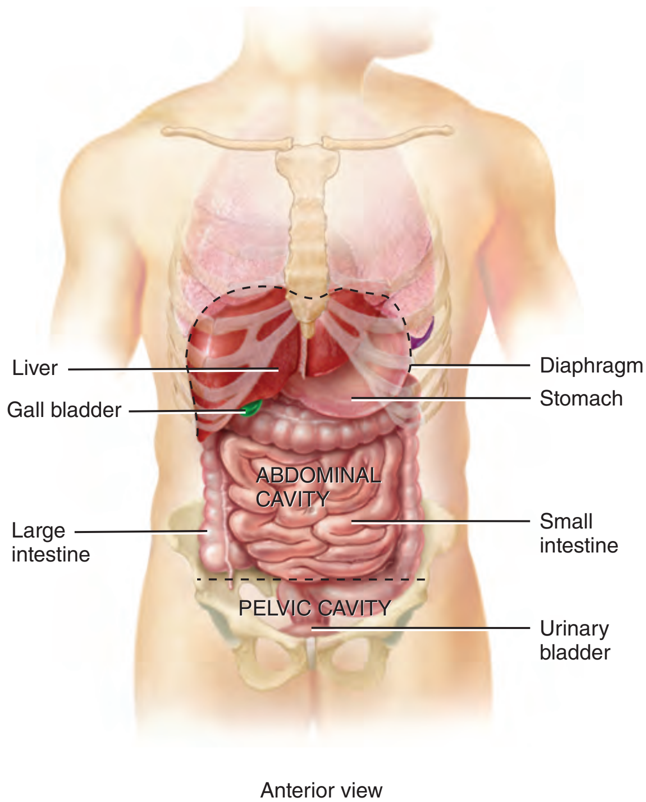
What is the name of the cavity that surrounds the heart? Which cavities surround the lungs?

thoracic organs except the lungs themselves. Among the structures in the mediastinum are the heart, oesophagus, trachea, thymus, and several large blood vessels that enter and exit the heart. The **diaphragm** (DĪ-a-fram = partition or wall) is a dome-shaped muscle that separates the thoracic cavity from the abdominopelvic cavity.

The **abdominopelvic cavity** (ab-dom′-i-nō-PEL-vik; see figure 1.9) extends from the diaphragm to the groin and is encircled by the abdominal muscular wall and the bones and muscles of the pelvis. As the name suggests, the abdominopelvic cavity is divided into two portions, even though no wall separates them (figure 1.11). The superior portion, the **abdominal cavity** (ab-DOM-i-nal; *abdomin-* = belly), contains the stomach, spleen, liver, gall bladder, small intestine, and most of the large intestine. The inferior portion, the **pelvic cavity** (PEL-vik; *pelv-* = basin), contains the urinary bladder, portions of the large intestine, and internal organs of the reproductive system. Organs inside the thoracic and abdominopelvic cavities are called **viscera** (VIS-er-a).

Figure 1.11 **The abdominopelvic cavity.** The black dashed lower line shows the approximate boundary between the abdominal and pelvic cavities.

The abdominopelvic cavity extends from the diaphragm to the groin.



To which body systems do the organs shown here within the abdominal and pelvic cavities belong? (*Hint:* refer to table 1.2.)

Thoracic and abdominal cavity membranes

A **membrane** is a thin, pliable tissue that covers, lines, partitions, or connects structures. One example is a slippery, double-layered membrane associated with body cavities that does not open directly to the exterior called a **serous membrane** (SĒR-us). It covers the viscera within the thoracic and abdominal cavities and also lines the walls of the thorax and abdomen. The parts of a serous membrane are (1) the *parietal layer* (pa-RĪ-e-tal), a thin epithelium that lines the walls of the cavities, and (2) the *visceral layer* (VIS-er-al), a thin epithelium that covers and adheres to the viscera within the cavities. Between the two layers is a potential space that contains small amount of lubricating fluid (*serous fluid*). The fluid allows the viscera to slide somewhat during movements, such as when the lungs inflate and deflate during breathing.

The serous membrane of the pleural cavities is called the **pleura** (PLOO-ra). The *visceral pleura* clings to the surface of the lungs, and the *parietal pleura* lines the chest wall, covering the superior surface of the diaphragm (see figure 1.10a). In between is the *pleural cavity,* filled with a small amount of lubricating serous fluid (see figure 1.10). The serous membrane of the pericardial cavity is the **pericardium** (per′-i-KAR-dē-um). The *visceral pericardium* covers the surface of the heart; the *parietal pericardium* lines the chest wall. Between them is the *pericardial cavity,* filled with a small amount of lubricating serous fluid (see figure 1.10). The **peritoneum** (per′-i-tō-NĒ-um) is the serous membrane of the abdominal cavity. The *visceral peritoneum* covers the abdominal viscera, and the *parietal peritoneum* lines the abdominal wall, covering the inferior surface of the diaphragm. Between them is the *peritoneal cavity,* which contains a small amount of lubricating serous fluid. Most abdominal organs are surrounded by the peritoneum. Some are not surrounded by the peritoneum; instead they are posterior to it [to limit repetition of peritoneum]. Such organs are said to be *retroperitoneal* (re′-trō-per-i-tō-NĒ-al; *retro-* = behind). The kidneys, adrenal glands, pancreas, duodenum of the small intestine, ascending and descending colons of the large intestine, and portions of the abdominal aorta and inferior vena cava are retroperitoneal.

In addition to the major body cavities just described, you will also learn about other body cavities in later chapters. These include the *oral (mouth) cavity,* which contains the tongue and teeth (see figure 24.5); the *nasal cavity* in the nose (see figure 23.1); the *orbital cavities (orbits),* which contain the eyeballs (see figure 7.3); the *middle ear cavities (middle ears),* which contain small bones (see figure 17.19); and the *synovial cavities,* which are found in freely movable joints and contain synovial fluid (see figure 9.3).

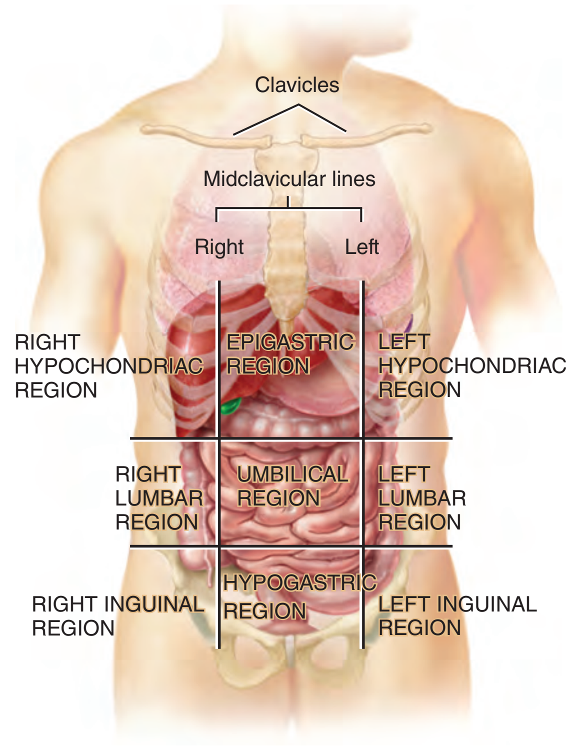
A summary of the major body cavities and their membranes is presented in the table included in figure 1.9.

Abdominopelvic regions and quadrants

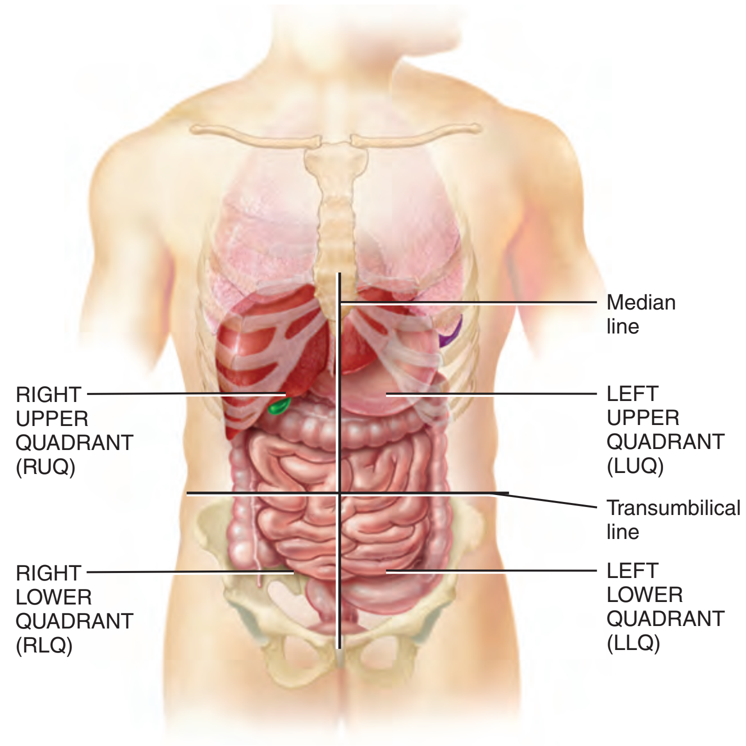
To describe the location of the many abdominal and pelvic organs more easily, anatomists and clinicians use two methods of dividing the abdominopelvic cavity into smaller areas. In the first method, two horizontal and two vertical lines, aligned like a tic-tac-toe grid, partition this cavity into nine **abdominopelvic regions** (figure 1.12a). The top horizontal line, the *subcostal line* (*sub-* = under; *costal* = rib), is drawn just inferior to the ribs, across the inferior portion of the stomach; the bottom horizontal line, the *transtubercular line* (trans-too-BER-kū-lar), is drawn just inferior to the tops of the hip bones. Two vertical lines, the left and right *midclavicular lines* (mid-kla-VIK-ū-lar), are drawn through the midpoints of the clavicles (collar bones), just medial to the nipples. The four lines divide the abdominopelvic cavity into a larger middle section and smaller left and right sections.

Figure 1.12 **Regions and quadrants of the abdominopelvic cavity.**

The nine-region designation is used for anatomical studies; the quadrant designation is used to locate the site of pain, tumours, or some other abnormality.



(a) Anterior view showing location of abdominopelvic regions



(b) Anterior view showing location of abdominopelvic quadrants

In which abdominopelvic region is each of the following found: most of the liver, ascending colon, urinary bladder, and most of the small intestine? In which abdominopelvic quadrant would pain from appendicitis (inflammation of the appendix) be felt?

The names of the nine abdominopelvic regions are **right hypochondriac** (hī′-pō-KON-drē-ak), **epigastric** (ep-i-GAS-trik), **left hypochondriac, right lumbar, umbilical** (um-BIL-i-kal), **left lumbar, right inguinal (iliac)** (IN-gwi-nal), **hypogastric (pubic)**, and **left inguinal (iliac).**

The second method is simpler and divides the abdominopelvic cavity into **quadrants** (KWOD-rantz; *quad-* = one-fourth), as shown in figure 1.12b. In this method, a midsagittal line (the *median line*) and a transverse line (the *transumbilical line*) are passed through the **umbilicus** (um-BI-li-kus; *umbilic-* = navel) or *belly button*. The names of the abdominopelvic quadrants are **right upper quadrant (RUQ), left upper quadrant (LUQ), right lower quadrant (RLQ),** and **left lower quadrant (LLQ).** The nine-region division is more widely used for anatomical studies, and quadrants are more commonly used by clinicians for describing the site of abdominopelvic pain, a tumour, or another abnormality.

CHECKPOINT

13. Locate each region shown in figure 1.5 on your own body, and then identify it by its anatomical name and the corresponding common name.
14. What structures separate the various body cavities from one another?
15. Locate the nine abdominopelvic regions and the four abdominopelvic quadrants on yourself, and list some of the organs found in each.

1.6 Medical imaging

OBJECTIVE

- Describe the principles and importance of medical imaging procedures in the evaluation of organ functions and the diagnosis of disease.

Medical imaging refers to techniques and procedures used to create images of the human body. Various types of medical imaging allow visualisation of structures inside our bodies and are increasingly helpful for precise diagnosis of a wide range of anatomical and physiological disorders. The grandparent of all medical imaging techniques is conventional radiography (x-rays), in medical use since the late 1940s. The newer imaging technologies not only contribute to diagnosis of disease, but they also are advancing our understanding of normal anatomy and physiology. Table 1.3 describes some commonly used medical imaging techniques. Other imaging methods, such as cardiac catheterisation, will be discussed in later chapters.

TABLE 1.3

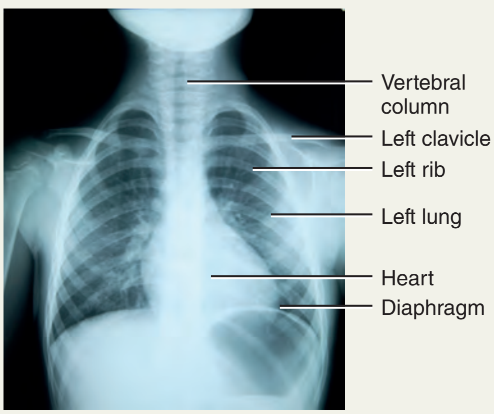
Common medical imaging procedures

RADIOGRAPHY

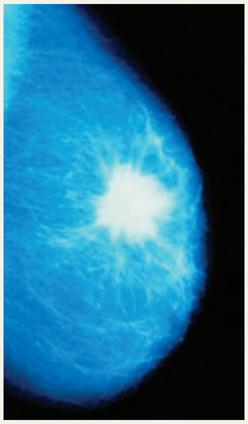
Procedure: A single barrage of x-rays passes through the body, producing an image of interior structures on x-ray–sensitive film. The resulting two-dimensional image is a *radiograph* (RĀ-dē-ō-graf′), commonly called an x-ray.

Comments: Relatively inexpensive, quick, and simple to perform; usually provides sufficient information for diagnosis. X-rays do not easily pass through dense structures, so bones appear white. Hollow structures, such as the lungs, appear black. Structures of intermediate density, such as skin, fat, and muscle, appear as varying shades of grey. At low doses, x-rays are useful for examining soft tissues such as the breast (**mammography**) and for determining bone density (**bone densitometry**).

It is necessary to use a substance called a contrast medium to make hollow or fluid-filled structures visible (appear white) in radiographs. X-rays make structures that contain contrast media appear white. The medium may be introduced by injection, orally, or rectally, depending on the structure to be imaged. Contrast x-rays are used to image blood vessels (**angiography**), the urinary system (**intravenous urography**), and the gastrointestinal tract (**barium contrast x-ray**).



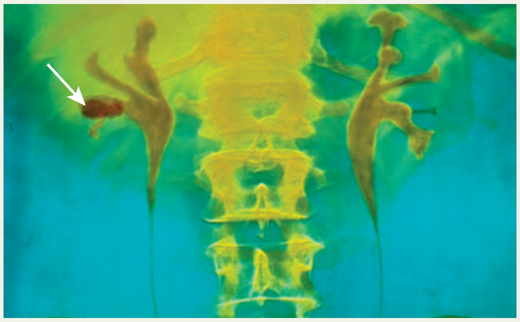
Radiograph of thorax in anterior view



Mammogram of female breast showing cancerous tumour (white mass with uneven border)

Bone densitometry scan of lumbar spine in anterior view

Angiogram of adult human heart showing blockage in coronary artery (arrow)



Intravenous urogram showing kidney stone (arrow) in right kidney

Barium contrast x-ray showing cancer of the ascending colon (arrow)

TABLE 1.3 CONTINUES