PRINCIPLES OF ANATOMY & PHYSIOLOGY

1ST ASIA–PACIFIC EDITION

TORTORA | DERRICKSON

BURKETT | DYE | COOKE
DIVERSI | MCKEAN | MELLIFONT
SAMALIA | PEOPLES




WILEY

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FIRST ASIA–PACIFIC EDITION

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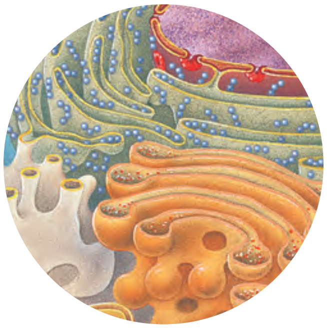

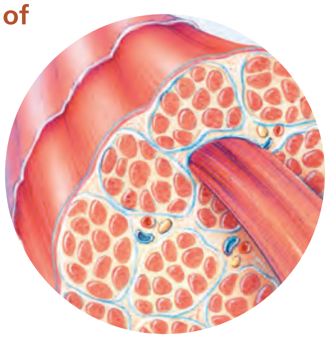

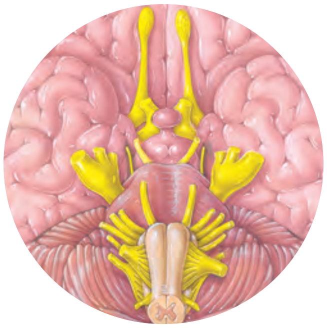

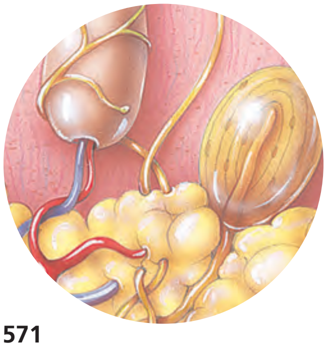

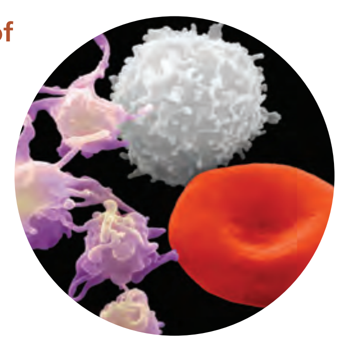

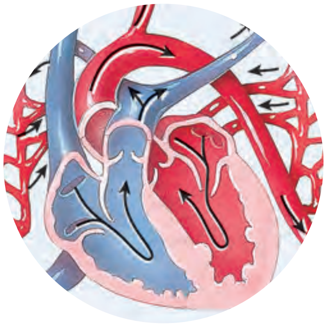

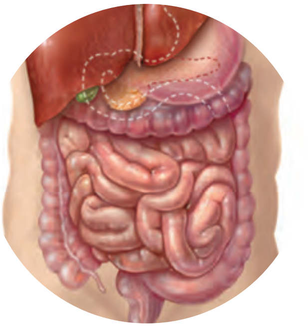

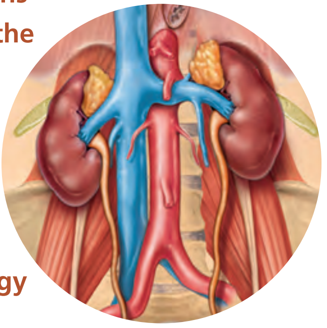

CLINICAL CONNECTIONS AND SPORT SPOTLIGHTS

FOCUS ON HOMEOSTASIS

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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Gregory Peoples
August 2015

ABOUT THE AUTHORS

Jerry Tortora is Professor of Biology and former Biology Coordinator at Bergen Community College in Paramus, New Jersey, where he teaches human anatomy and physiology as well as microbiology. He received his bachelor's degree in biology from Fairleigh Dickinson University and his master's degree in science education from Montclair State College. He is a member of many professional organisations, including the Human Anatomy and Physiology Society (HAPS), the American Society of Microbiology (ASM), the American Association for the Advancement of Science (AAAS), the National Education Association (NEA), and the Metropolitan Association of College and University Biologists (MACUB).

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.

Bryan Derrickson is Professor of Biology at Valencia College in Orlando, Florida, where he teaches human anatomy and physiology as well as general biology and human sexuality. He received his bachelor's degree in biology from Morehouse College and his Ph.D. in cell biology from Duke University. Bryan's study at Duke was in the Physiology Division within the Department of Cell Biology, so while his degree is in cell biology, his training focused on physiology. At Valencia, he frequently serves on faculty hiring committees. He has served as a member of the Faculty Senate, which is the governing body of the college, and as a member of the Faculty Academy Committee (now called the Teaching and Learning Academy), which sets the standards for the acquisition of tenure by faculty members. Nationally, he is a member of the Human Anatomy and Physiology Society (HAPS) and the National Association of Biology Teachers (NABT). Bryan has always wanted to teach. Inspired by several biology professors while in college, he decided to pursue physiology with an eye to teaching at the college level. He is completely dedicated to the success of his students. He particularly enjoys the challenges of his diverse student population, in terms of their age, ethnicity, and academic ability, and finds being able to reach all of them, despite their differences, a rewarding experience. His students continually recognise Bryan's efforts and care by nominating him for a campus award known as the 'Valencia Professor Who Makes Valencia a Better Place to Start'. Bryan has received this award three times.

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.

Danielle Dye is a Lecturer in human biology, histology, biotechnology and research methods at Curtin University, having commenced there in 2010 as an Early Career Research Fellow. She holds a PhD in cell biology from the University of Western Australia and a BSc (Honours) from Curtin University. Danielle's research focuses on the interactions between cells and the extracellular environment, with a dual focus on melanoma metastasis and muscle regeneration. She has published over thirty journal articles and one book chapter. She is active on the Western Australia committees of the Australian Society for Medical Research and the Human Genetics Society of Australasia.

Julie Cooke is an Assistant Professor Anatomy and Physiology in the discipline of sport and exercise science at the University of Canberra. Julie commenced her teaching career in 1998 at the Copenhagen International School where she taught biology. She completed a BSc (Hons) at Flinders University, South Australia, and received her PhD from the University of Adelaide in 2000. Julie has a passion for teaching and enjoys engaging students so that studying is easier and more enjoyable.

She is an active member of Exercise Sports Science Australia and Sports Medicine Australia.

Tara Diversi (BHSc, GradDipPsyc, PostGradDipPsyc, MBA, MNutr&Diet) is an Assistant Professor of Nutrition and Dietetics at Bond University. She is an accredited practising dietitian and advanced sports dietitian. Her current research is aligned with her sporting passion of marathon and channel swimming. She has worked a number of years as an expert in holistic nutrition in private practice, private and public health consultancy, media and academia. Tara combines her expertise in nutrition with food psychology to help people achieve outcomes that are personalised, sustainable and suited to their individual lifestyle and goals. She lives with her family on their grass-fed cattle property in north Queensland.

Mark McKean is a Research Fellow at the University of the Sunshine Coast. He has an extensive background in both fitness and strength and conditioning, coaching athletes in a range of sports to Olympic, Paralympic and World Championship medals. Mark is an accredited exercise physiologist with ESSA, a certified strength and conditioning specialist through NSCA America, a level three strength and conditioning coach and master coach with ASCA, and a level three exercise professional with Fitness Australia. Mark provides consulting services to sporting and fitness organisations, and conducts workshops and lectures both nationally and internationally.

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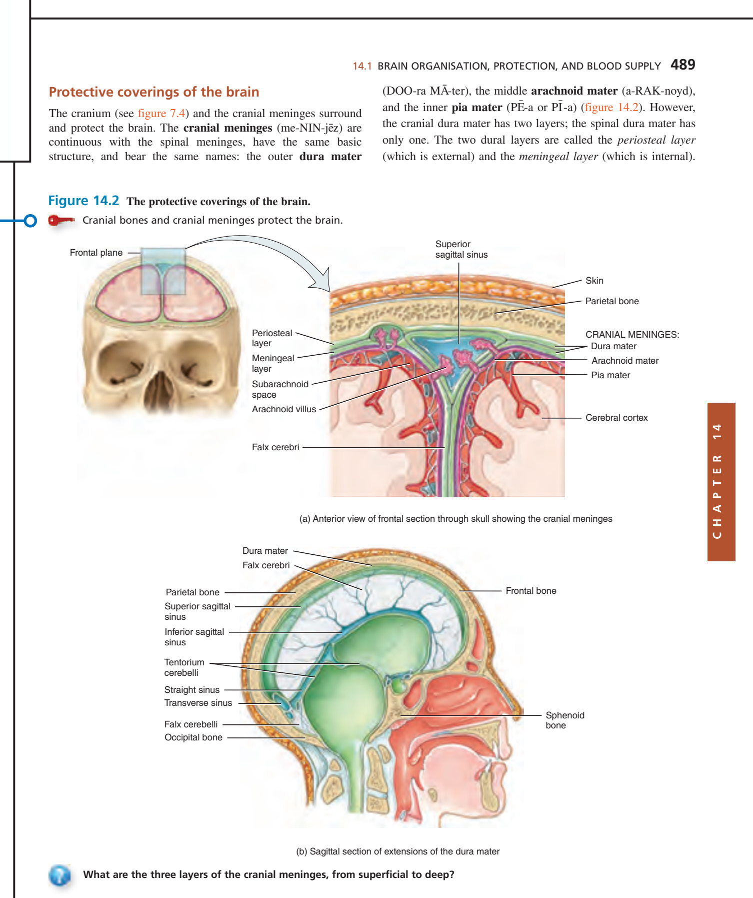
A short **opening case** frames the context of the chapter using a real-world clinical or sports example relevant to Australia, New Zealand and the Asia–Pacific.



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.

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

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.

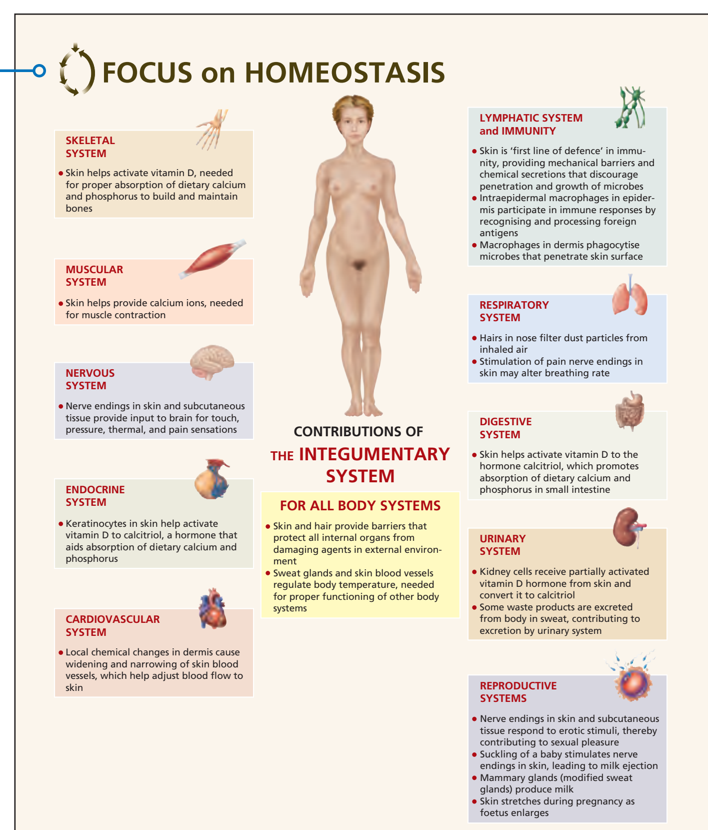
The term **thorax** refers to the entire chest region. The skeletal part of the thorax, the **thoracic cage,** is a bony enclosure formed by the sternum, ribs and their costal cartilages, and the bodies of the thoracic vertebrae (see exhibits 7.L and 7.M). The costal cartilages attach the ribs to the 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.



FOCUS on HOMEOSTASIS

SKELETAL SYSTEM
- Skin helps activate vitamin D, needed for proper absorption of dietary calcium and phosphorus to build and maintain bones

MUSCULAR SYSTEM
- Skin helps provide calcium ions, needed for muscle contraction

NERVOUS SYSTEM
- Nerve endings in skin and subcutaneous tissue provide input to brain for touch, pressure, thermal, and pain sensations

ENDOCRINE SYSTEM
- Keratinocytes in skin help activate vitamin D to calcitriol, a hormone that aids absorption of dietary calcium and phosphorus

CARDIOVASCULAR SYSTEM
- Local chemical changes in dermis cause widening and narrowing of skin blood vessels, which help adjust blood flow to skin

CONTRIBUTIONS OF THE INTEGUMENTARY SYSTEM

FOR ALL BODY SYSTEMS
- Skin and hair provide barriers that protect all internal organs from damaging agents in external environment
- Sweat glands and skin blood vessels regulate body temperature, needed for proper functioning of other body systems

LYMPHATIC SYSTEM and IMMUNITY
- Skin is 'first line of defence' in immunity, providing mechanical barriers and chemical secretions that discourage penetration and growth of microbes
- Intraepidermal macrophages in epidermis participate in immune responses by recognising and processing foreign antigens
- Macrophages in dermis phagocytise microbes that penetrate skin surface

RESPIRATORY SYSTEM
- Hairs in nose filter dust particles from inhaled air
- Stimulation of pain nerve endings in skin may alter breathing rate

DIGESTIVE SYSTEM
- Skin helps activate vitamin D to the hormone calcitriol, which promotes absorption of dietary calcium and phosphorus in small intestine

URINARY SYSTEM
- Kidney cells receive partially activated vitamin D hormone from skin and convert it to calcitriol
- Some waste products are excreted from body in sweat, contributing to excretion by urinary system

REPRODUCTIVE SYSTEMS
- Nerve endings in skin and subcutaneous tissue respond to erotic stimuli, thereby contributing to sexual pleasure
- Suckling of a baby stimulates nerve endings in skin, leading to milk ejection
- Mammary glands (modified sweat glands) produce milk
- Skin stretches during pregnancy as foetus enlarges

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.

CHAPTER REVIEW **143**

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-thē-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**.

CHAPTER REVIEW **237**

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

238 CHAPTER 7 • THE SKELETAL SYSTEM: THE AXIAL SKELETON

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

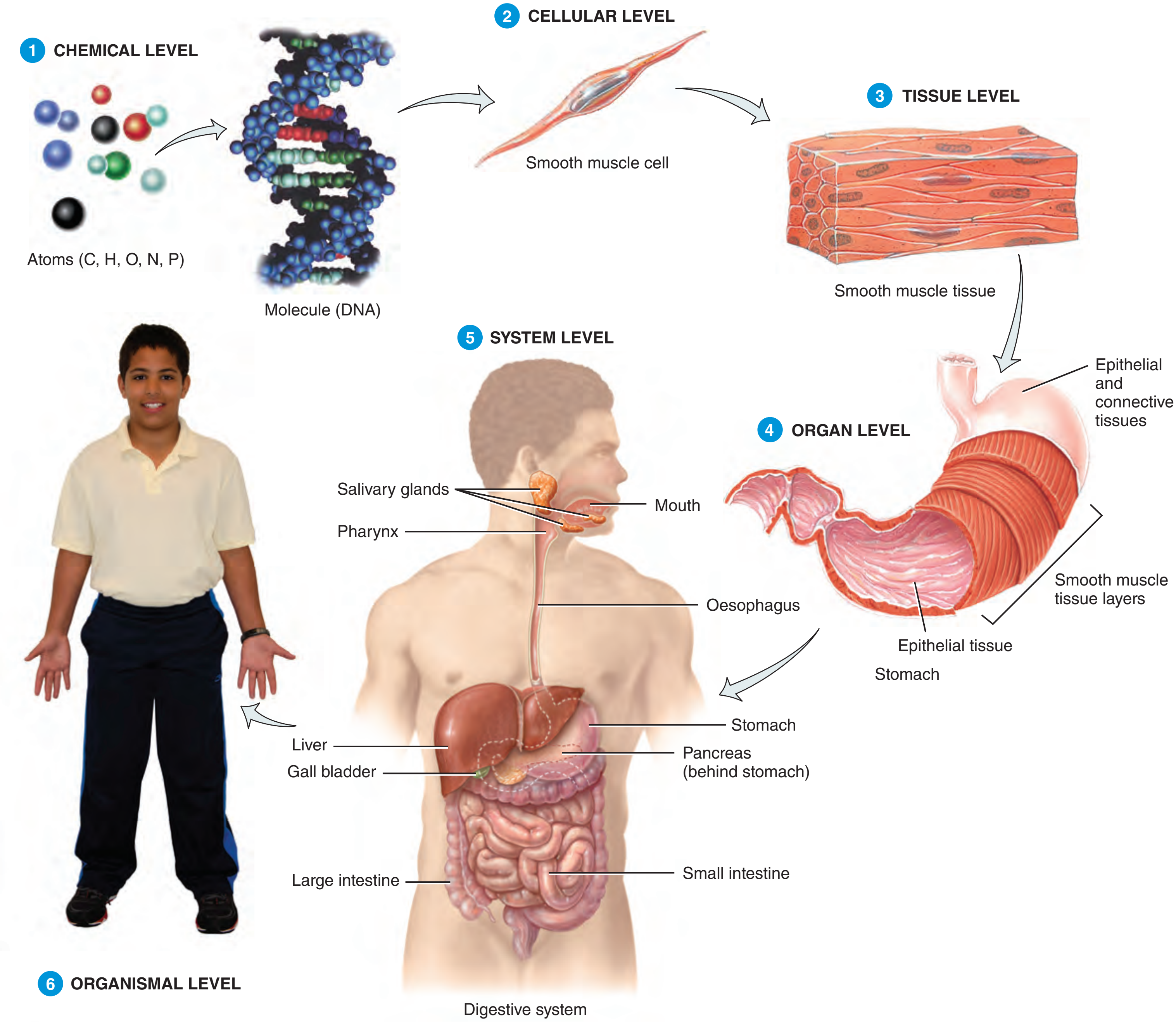
BRANCH OF ANATOMY	STUDY OF	BRANCH OF PHYSIOLOGY	STUDY OF
Embryology (em′-brē-OL-ō-jē; *embry-* = embryo; *-logy* = study of)	The first eight weeks of development after fertilisation of a human egg.	**Neurophysiology** (NOOR-ō-fiz-ē-ol′-ō-jē; *neuro-* = nerve)	Functional properties of nerve cells.
Developmental 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

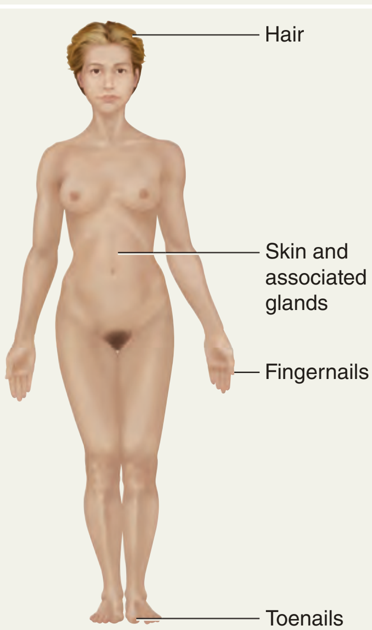
TABLE 1.2

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**.

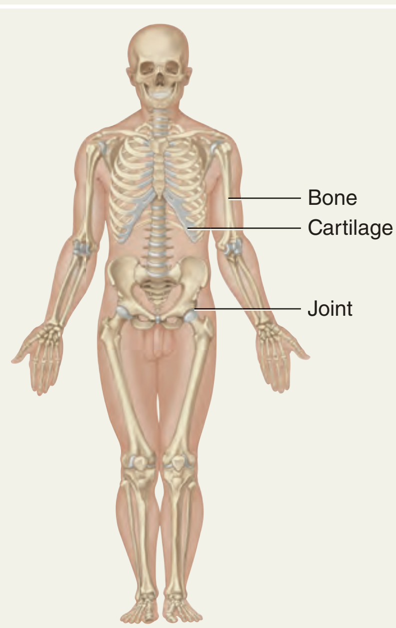
Functions: Protects body; helps regulate body temperature; eliminates some wastes; helps make vitamin D; detects sensations such as touch, pain, warmth, and cold; stores fat and provides insulation.



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

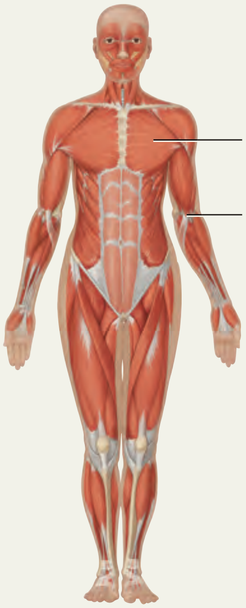
Certain processes distinguish organisms, or living things, from nonliving things. Following are the six most important life processes of the human body.

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.

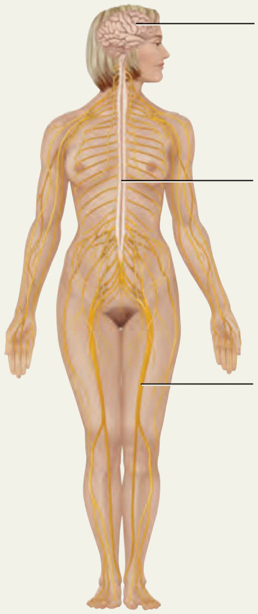


TABLE 1.2 CONTINUES

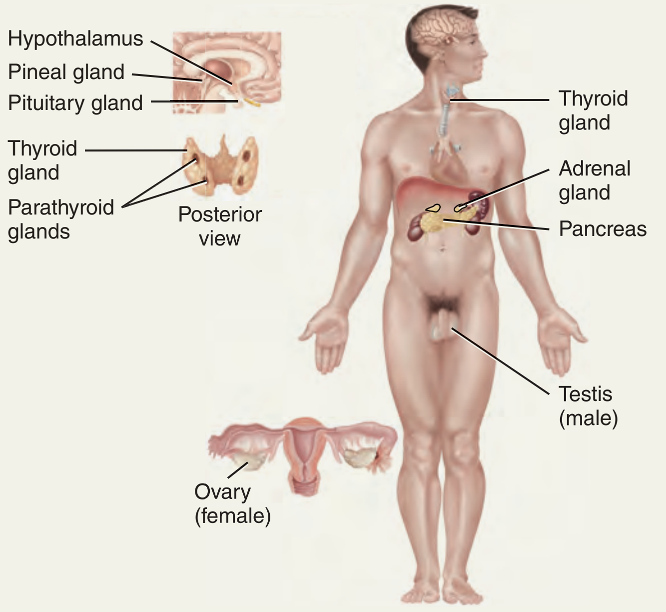
TABLE 1.2 CONTINUED

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.

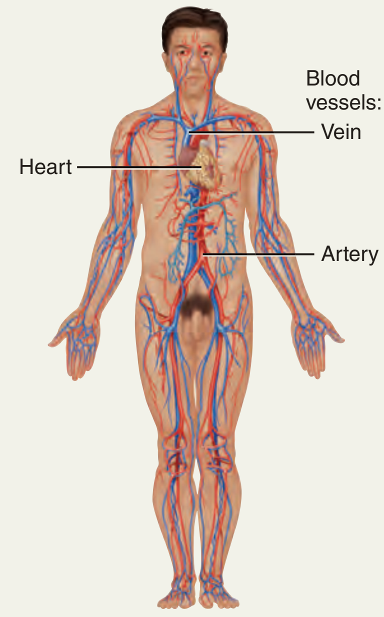
Functions: Regulates body activities by releasing hormones (chemical messengers transported in blood from endocrine gland or tissue to target organ).



CARDIOVASCULAR SYSTEM (CHAPTERS 19–21)

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

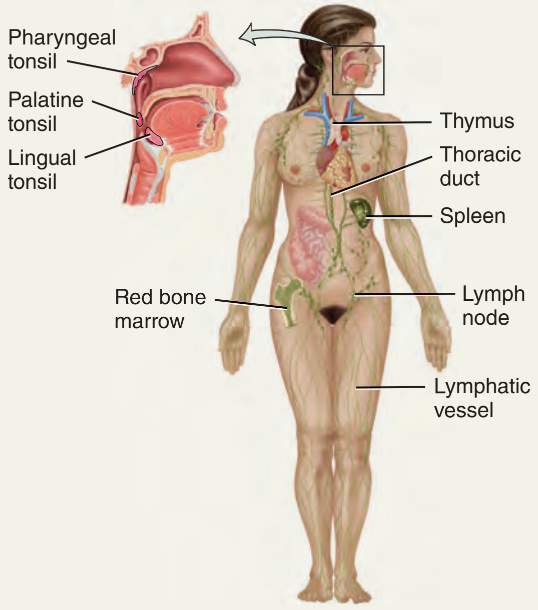
Functions: Heart pumps blood through blood vessels; blood carries oxygen and nutrients to cells and carbon dioxide and wastes away from cells and helps regulate acid–base balance, temperature, and water content of body fluids; blood components help defend against disease and repair damaged blood vessels.



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).

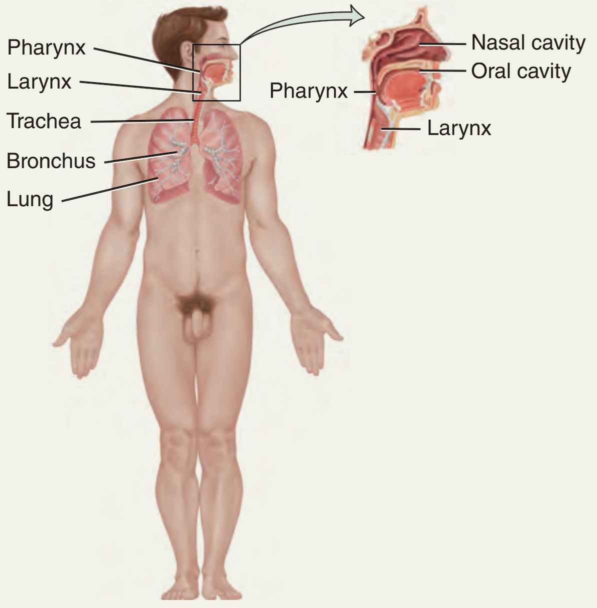
Functions: Returns proteins and fluid to blood; carries lipids from gastrointestinal tract to blood; contains sites of maturation and proliferation of B cells and T cells that protect against disease-causing microbes.



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.

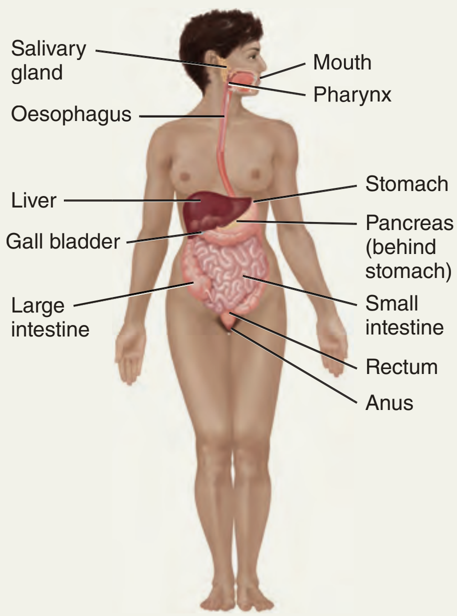
Functions: Transfers oxygen from inhaled air to blood and carbon dioxide from blood to exhaled air; helps regulate acid–base balance of body fluids; air flowing out of lungs through vocal cords produces sounds.



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.**

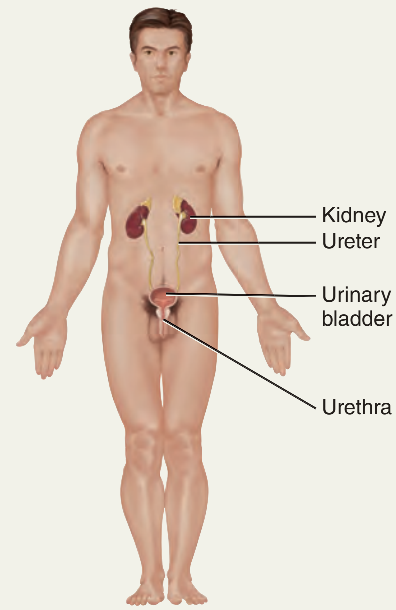
Functions: Achieves physical and chemical breakdown of food; absorbs nutrients; eliminates solid wastes.



URINARY SYSTEM (CHAPTER 26)

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

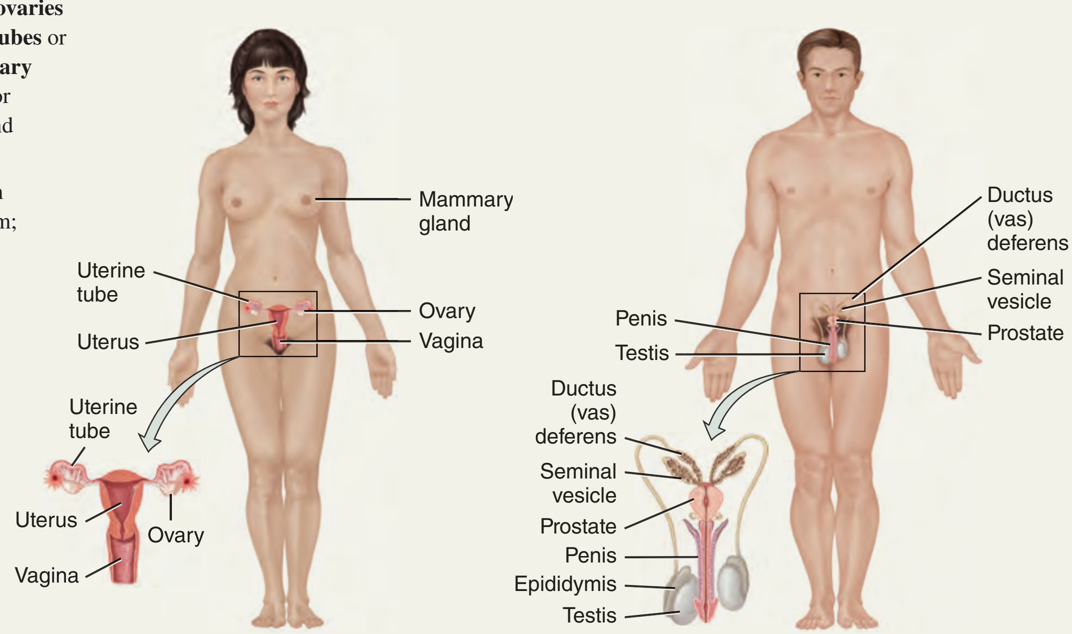
Functions: Produces, stores, and eliminates urine; eliminates wastes and regulates volume and chemical composition of blood; helps maintain the acid–base balance of body fluids; maintains body's mineral balance; helps regulate production of red blood cells.



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.

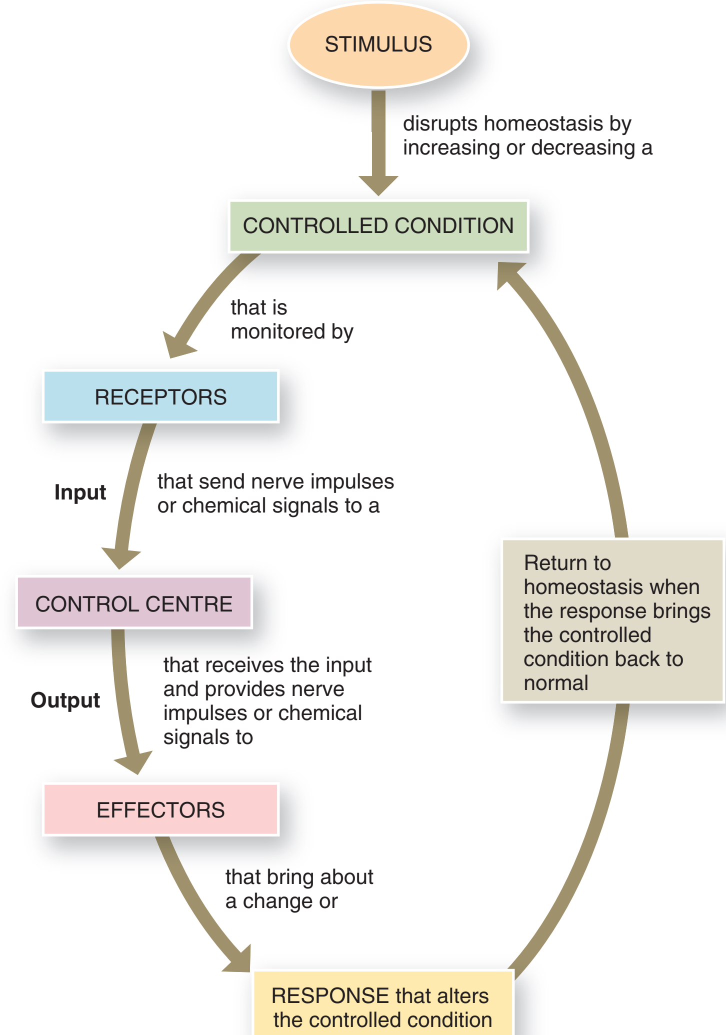
Feedback systems

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