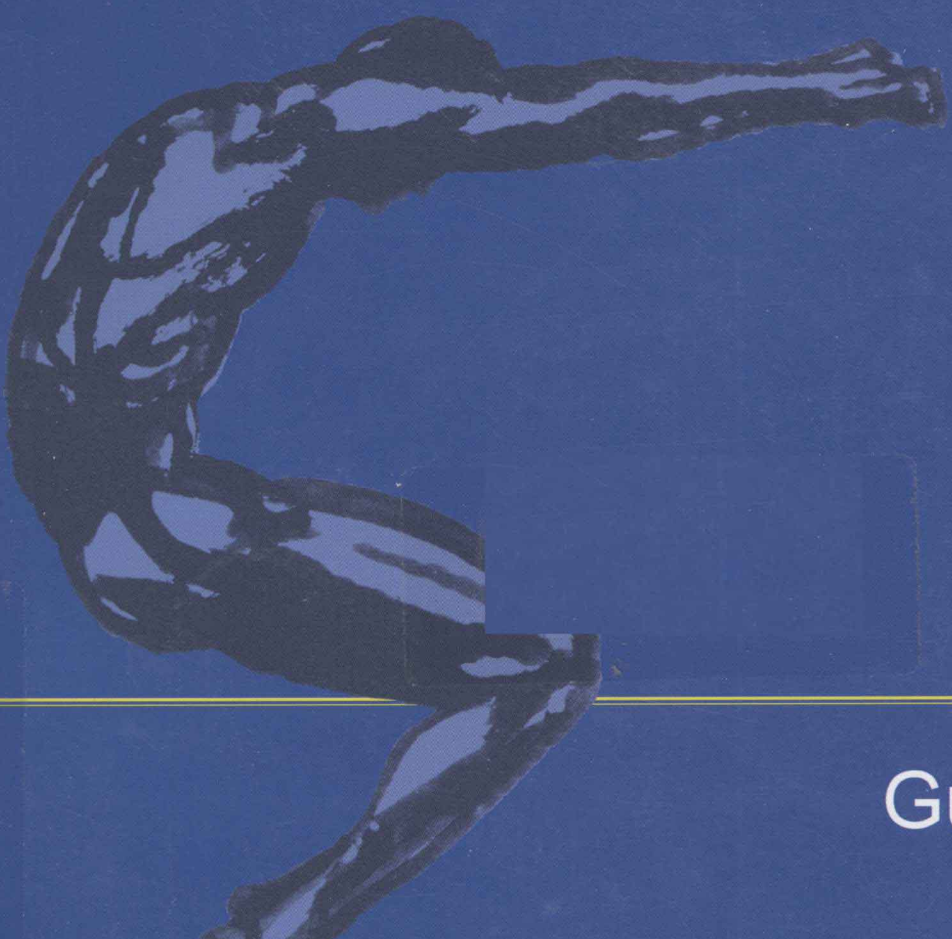
HUMAN Anatomy



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Preface

Students of the medical and allied sciences require a solid grounding in human anatomy if they want to fully understand the key aspects of all medical courses and to pursue their future careers in health-related professions. The structure of the human body, as studied in human anatomy, represents not only an innate beauty of biological machines essential for our lives, but a physical basis to determine how the body functions or goes wrong. Based on this, the importance of human anatomy for medical education cannot be overestimated.

This textbook, designed for a one-semester human anatomy course, is aimed to provide elementary knowledge and basic concepts of human anatomy and to furnish an accessible framework of medical morphology for students majoring in medicine and other health-care programs. Although human anatomy is a classical subject in the medical course system, the teaching of human anatomy has been greatly challenged in recent years due to an explosion of information and an updating of ideas in medical science. To ensure enough knowledge to be learned by students without necessarily increasing their learning time, we rely on the collective wisdom and combined experience of all authors to condense the subject essentials into this student-friendly text of 5 units, 19 chapters. The text contents are rigorously chosen to acquaint students with clear views on anatomical structures and relationships, and the text layout is ingeniously organized to allow each chapter to become a freestanding reading material and yet to make different chapters well inter-correlated.

Anatomy is a visual science, and the learning of it by students can benefit from ample illustrations with combination of aesthetic beauty and scientific accuracy in the textbook. The total 466 figures of high quality have been included to integrate with the text. They are created based on measurements or observations of dissected materials or by reference to the standard atlas from trusted anatomy bibles by skilled professionals among them some are renowned artists. We believe that these artworks will enable students to build a pictorial insight into anatomical descriptions and to comprehend the issues that they find particularly difficult through the text reading.

For most students, learning human anatomy is considered as an endeavor of rote memorization, and they are often plagued by the massive amount of anatomical materials. Also, studying anatomy is, to a certain degree, similar to studying a foreign language because students must be familiar with the anatomical terminology before they understand the materials and further apply them. To help students overcome these psychological barriers, we have introduced a few pedagogical tips into the narrative in addition to keeping a unified writing style to make the text readable and accurate. These tips cover the end-of-chapter summary to review the main points of each chapter, the brief discussion on the clinical implications of some in-chapter examples, and the color-code scheme for many drawings to highlight the different anatomical positions, which will encourage students to concern about a more thoughtful discovery of facts as well as facts themselves. The anatomical terms used in our book follow the international standard on which anatomical vocabulary should be based.

I owe a real debt of gratitude to all the authors who are qualified and experienced professors from eight medical universities or colleges in China, and have contributed to the preparation of this textbook through their excellent work and full cooperation. A special gratitude is owed to the illustrators of our book for their fantastic creation. We also acknowledge and thank many experts as they evaluated our manuscripts and page proofs, and provided valuable comments and suggestions. Finally, the critical feedback for improving our book is always welcome.

Gu Xiaosong

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1. Definition of Human Anatomy

Human anatomy, a morphological branch of biology is a science concerned with the normal patterns and structures of the human body. The term anatomy is derived from two Greek words, meaning "to cut up". Physiology is an extension beyond anatomy about the human body, as a science, it is concerned with the function of the body. The term physiology is also derived from two Greek words, meaning "the study of the nature". Anatomy and physiology are both subdivisions of the life sciences, the study of living organisms. The anatomy of every structure of the body is adapted to performing a function or perhaps several functions. Natural selection eliminates organisms with inappropriate structures and functions and determines which favorable structures will be passed from one generation to the next.

The dissection of human cadaver has been the basis for understanding the structure and function of the human body for a long time. Each beginning student can directly discover and learn materials studied as the structures of the body are systematically explored. The anatomical terms, which students learn while becoming acquainted with body structures, represent the work of a great number of dedicated past anatomists who dissected, diagramed, described, and named the multitude of body parts.

Human anatomy will always be a relevant science. It is important to have a good personal understanding of body functions. It is more than so to the medical profession which is concerned, among others, with body's dysfunctions. Human anatomy is no longer confined to isolated observations and descriptions of body structures, but also includes the complexities the body functions. The science of anatomy is dynamic and has always been a vital one because anatomists have dared to explore the intricate territories of the human body. The importance of human anatomy today is in functional human anatomy to show that it is an indispensable science for today and will be so in the future. Human anatomy is a practical, applied science, forming the foundation of an understanding of physical performance and body health. The objective of this course is to help students to become well-informed and conversant in anatomy, while providing for them a solid foundation for medical research.

2. Selected Subdisciplines of Anatomy

Human Anatomy is a large discipline of science. Some of its main subdisciplines are the Gross Anatomy, Histology, Cytology, and Embryology.

(1) **Gross anatomy** is the study of the structures with the unaided eye. The course of gross anatomy provides the necessary foundation for medical and paramedical students. The main subdisciplines of gross anatomy on its turn are: systemic anatomy, regional anatomy, sectional anatomy, and clinical anatomy. The clinical anatomy may embrace anatomy in many aspects with the subdisciplines such as surgical anatomy, microsurgical anatomy, developmental anatomy, anatomy of aging, radiological anatomy which uses mainly X-rays to obtain pictures, and imaging anatomy which uses ultrasound, Magnetic Resonance Imaging (MRI), Positron Transmission Tomography (PET), Computerized Tomography (CT), and other technigues to obtain pictures.

(2) **Microscopic anatomy** studies structures smaller than 0.1 mm which can be seen with the aid of a light microscope. Cytology (study of cells), histology (study of tissues), and embryology (study of embryos) are also subspecialities of anatomy and provide additional information about structures and functions of the human body. Minute details of the cells and tissues are obtained with the aid of electron microscopes. Recently, new techniques in staining, histochemistry, and immunohistochemistry are furher enhanced in the use of light and/or electron microscopes for the examination of microstructures and submicrostructures.

(3) **Applied anatomy** is a subspeciality of anatomy and uses the knowledge and principles of anatomy in specific fields of human activity such as arts, sports and athletic training, emotional expression, etc.

3. Organization of Human Body

(1) Body organization

A human body is organized at many levels from the molecular structures to the whole body. However, the organizational levels that are tackled here are the cellular, tissue, organ and system level organizations.

1) **Cells**: The cells are the basic structural and functional components of life. Humans are multicellular organisms composed of about 60 to 100 trillion cells. It is at the cellular level that the vital functions of life, such as metabolism, growth, irritability and adaptability, repair, and reproduction are carried out. All cells composing the human body contain many types of cells with distinct structures, specialized to perform some specific functions. Among these many types of cells are the bone cells, muscle cells, fat cells, blood dells, and nerve cells.

2) **Tissues**: Tissues are layers or aggregations of similar cells, with the materials around them to perform specific functions. For example, cardiac (heart) muscle is a type of tissue whose function is to contract and pump the blood throughout the body. There are four kinds of tissues in an adult human body:

Epithelial tissue: Simple epithelial tissue, stratified epithelial tissue, and glandular epithelial tissue.

Connective tissue: Cartilage, bone, blood, hematopoietic tissue, loose connective tissue, dense connective tissue, connective tissue with special properties.

Muscle tissue: Skeletal muscle tissue, cardiac muscle tissue, and smooth muscle tissue.

Nervous tissue: Neurons(nerve cells) and neuroglia(neuroglial cells).

3) **Organ**: An organ is a structure composed of two or more tissues integrated together to perform some particular functions. Organs throughout the body vary greatly in size and function. Examples of organs are the heart, spleen, pancreas, ovary, skin, and even any bone within the body. Each organ usually has one or more primary tissues and several secondary tissues. In the stomach, for example, the internal epithelial lining is considered to be its primary tissue as the basic functions of secretion and absorption occur within this layer. Secondary tissues of the stomach are the supporting connective tissue and vascular, nervous, and muscular tissues.

4) **System**: The systems of the body make up the advanced level of structural organization. A system consists of various organs that have similar or related functions. Examples of systems, with their constituents, are as follows:

Locomoter system: Bones, articulations, and skeletal muscles.

Digestive system: Alimentary canals and Alimentary glands.

Respiratory system: Respiratory tracts and lungs.

Urinary system: Kidneys, urinary canals, and urinary bladder.

Reproductive system(Male and Female): External reproductive organs and internal reproductive organs.

Circulatory system (Cardiovascular system): The heart, arteries, blood vessels and blood lymphatic system; lymphatic tissue, lymphatic vessels and lymphatic organs.

Sensory system: General sensory receptors distributed almost all over the body, and specialized sensory, housed in specific organs such as the eyes, ears, tongue, nose.

Nervous system: Central nervous system(CNS) and peripheral nervous system(PNS).

Endocrine system: Endocrine tissue and endocrine organs.

Digestive system, respiratory system, urinary system, and reproductive system are together referred to as the visceral systems. Certain organs may be serving several systems. The pancreas, for example, is an essential component of both the endocrine and digestive systems. All the systems of the body are interrelated and function together, constituting the total organism. In a systemic approach to studying anatomy, the functional relationships of various organs within a system are emphasized.

(2) **Body regions**: The human body may be examined and divided into several regions that can be identified on the surface of the body. Learning the terminology used in reference to these regions now will help to learn the names of underlying structures later. The major body regions are the head, neck, trunk, upper extremities, and lower extremities. The trunk is usually divided into the thorax, abdomen, and pelvis.

Head: The head consists of a cranial region that covers and supports the cranial cavity and brain, and a facial region that consists of the eyes, nose, and mouth.

Neck: The neck (cervix) has two divisions: the cervical region and the nape. The neck supports the head and helps the head to move.

Thorax: The thorax consists of the thoracic wall and thoracic cavity. The thoracic region can be subdivided into the anterior, lateral, and posterior(back) regions. The thoracic cavity includes the lungs and mediastinum.

Abdomen: The abdomen is located below the thorax and has two component parts: the abdominal wall and abdominal cavity. The abdominal wall is subdivided into anterolateral regions and posterior(back) regions. The abdominal cavity includes many visceral organs such as the liver, stomach, spleen, pancreas, kidneys, and intestines.

Pelvis: The pelvic region forms the lowest portion of the trunk which consists of the pelvic wall and pelvic cavity. The surface area below the pelvic cavity is perineum that contains the external sex organs and the anal opening.

Upper extremities(Limbs): The upper extremities are anatomically divided into a shoulder, arm(brachium), forearm, and hand each.

Lower extremities (Limbs): The lower extremities are composed of a thigh, knee, leg, and foot each.

The regional approach to study anatomy has been an indispensable part of the medial education and application because it provides the necessary appreciation of the structural relationships between components of several systems observed simultaneously.

(3) Human anatomical characteristics

Human beings have certain anatomical characteristics that are species-specific and are used in taxonomical identification and distinction. Some of the characteristics between humans and other species are quite well developed in other species when combined with the human brain. These structural characteristics provide unique distinctive features. Some important ones of these are as follows:

1) **Brain size and development**: The average human brain weighs between 1 350 and 1 500 g. That is, humans have a large brain-to-body weight ratio. More important than that the way the components of the brain are developed; certain specialized regions and structures within the brain account for emotion, thought, reasoning, memory, and even precise coordinated movement, specific to human species.

2) **Type of locomotion**: Humans stand and walk on two legs; they are said to be bipedal. However, corresponding upright posture has some consequences as evolutionary costs as diagnostic structural features in the cases of the sigmoid (S-shaped) curvature of the spine, the peculiar anatomy of the hip and thighs and the arched feet, ending up in clinical problems in some individuals.

3) **Opposable thumb**: The human thumb joint is structurally adapted for tremendous versatility for grasping objects. Some primates have opposable thumbs too, but human thumb joints are the best-developed ones. The opposable movement enables humans to use tools to work, an evolutionary advantageous gain as it is thought to be a result of man working in the process of evolution.

4) **Vocal structure**: Humans are endowed with articulate spoken language. Very foundation of human civilization and progress due to the presence of the vocal organ and a well-developed brain.

5) **Stereoscopic vision**: Humans are some animals have stereoscopic vision. The eyes are located on one plane so that when they are focused upon an object, one views the object from two angles and integrations in the brain lead to stereoscopic vision. Stereoscopic vision enables humans to have depth perception, and three-dimensional vision.

There are many other characteristics that get humans aside from other species such as the number and arrangement of vertebrae, the types and numbers of teeth, well-developed facial muscles, and the structural design of various body organs.

4. Anatomical Terminology

All of the descriptive terms of planes and terms of direction used in anatomy are standardized to minimize the information loss in communication related to anatomy.

(1) **Anatomical position**: All of the terms of direction that describe the position of one body part in relation to another are made in reference to the anatomical position. In the anatomical position, the body is standing erect; the feet are together, parallel to one another and flat on the floor, the eyes are facing forward, and the arms are on sides of the body with the palms of the hands also facing.

(2) **Axes and planes**: In order to visualize and study the structural arrangements of various organs, the body is imagined to be sectioned and diagramed according to some conventional axes and planes of reference (Fig. 0-1).

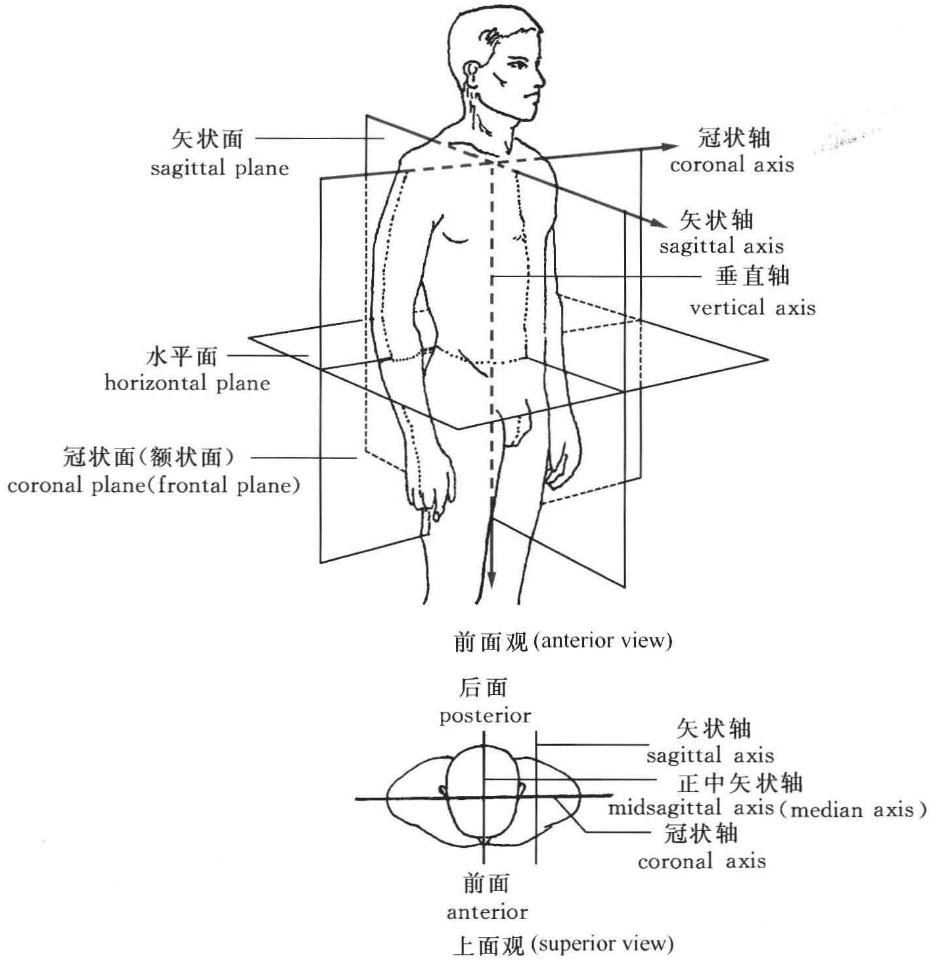

Fig. 0-1 The axis and surface in human body

1) **Axes**: Three dimensional axes-the vertical, sagittal, and coronal axis, are used as stereoscopic coordinates, in reference to which organs can be located and described at any points of space.

Vertical axis: an axis in the up-down orientation, vertical to the horizontal plane.

Sagittal axis: an axis in the front-back orientation, parallel to the horizontal plane.

Coronal or frontal axis: an axis in the right-left orientation, parallel to the horizontal plane and vertical to the vertical axis.

2) **Planes**: three main planes: sagittal, coronal, and transverse planes, which are frequently used for the purpose of descriptions. Reference to these planes is paramount in radiological imaging.

Sagittal plane: A midsagittal plane runs vertically through the midst of the body, dividing a body into right and left halves. Other sagittal planes also extend vertically and divide the body into unequeal right and left parts.

Coronal plane: Coronal, or frontal, planes also run vertically and divide the body into front and back portions.

Transverse plane: The transverse plane, also called horizontal or cross-sectional plane, divides the body into superior and inferior parts.

3) **Directional terms**: Directional terms are used to locate the position of structures, surfaces, and regions of the body. These terms are used always to describe body parts relative to others.

Directional terms for the human body:

Term	Meaning
Superior	toward the head or up
Inferior	away from the head or down
Anterior	toward the front
Posterior	toward the back
Medial	toward the midline of the body
Lateral	away from the midline of the body
Internal	away from the surface of the body, inside
External	toward the surface of the body, outside
Proximal	toward the trunk of the body, closer to the center
Distal	away from the trunk of the body, away from the center
Visceral	related to internal organs
Parietal	related to the body walls
Cranial	near the head or upper part of the head
Caudal	toward the end of the vertebral column
Ventral	or anterior, toward the front
Dorsal	or posterior, toward the back
Ulnar	medial side of upper extremity
Radial	lateral side of upper extremity
Tibial	medial side of lower extremity
Fibular	lateral side of lower extremity
Vertical	in up-downward orientation
Horizontal	perpendicular to the vertical plane in right-left orientation
Central	in or near the center
Profundal	deep, away from the surface
Superficial	at or near the surface

5. Objectives to Study Human Anatomy

Anatomy is a foundational discipline for many other disciplines, such as medicine, nursing, paramedicine, dentistry, medical technology, physical therapy, and athletic training. This course of anatomy will have the following objectives:

1) To provide the sufficient material and knowledge so that

the students have an adequate appreciation of life and a better understanding of the structure, function, and magnificence of the human body.

2) To identify and state clearly the basic concepts and accompanying information pertinent to human anatomy.

3) To provide a balanced, correlated presentation of anatomy at the developmental, cellular, histological, clinical, and gross anatomical levels.

4) To develop in a sufficient anatomical vocabulary so that the students understand and are conversant with medical terminology.

5) To encourage proper care of the body so that a more healthy and productive life can be enjoyed.

6) To familiarize the reader with the history of the science of anatomy, from the early beginnings to the recent advances, so that the students develop their competence in scientific research related to anatomy and/or life sciences.

6. Chinese Summary

人体解剖学是研究人体正常形态、结构的科学,属于生物学中的形态学范畴。根据学习目的、研究方法及应用需要的不同可分为系统解剖学和局部解剖学。

构成人体最基本的形态、功能单位是细胞。由细胞和细胞间质构成组织,人体的基本组织有上皮组织、结缔组织、肌组织和神经组织四种。几种不同组织组合成具有一定形态的结构称器官。若干器官组合起来共同完成某种生理功能,构成系统。人体有运动系统、消化系统、呼吸系统、泌尿系统、生殖系统、脉管系统(包括心血管系统和淋巴系统)、感觉系统、神经系统和内分泌系统。

解剖学姿势,亦称标准姿势:身体直立,两眼平视正前方,上肢自然下垂于躯干两侧,手掌朝前,两下肢及足尖并拢。在描述人体结构时,包括标本、模型或临床上处于任何体位的患者都必须以标准姿势为准。

在标准姿势下,设定了垂直轴、矢状轴、冠状轴三个轴及表达整体或局部结构位置的水平面、矢状面、冠状面三个互相垂直的平面。

为了正确地描述解剖学姿势下人体各器官或结构的方位及相互关系,还规定了常用的方位术语。如上和下、内和外、前和后、浅和深、近侧和远侧、内侧和外侧等。

(Gu Xiaosong, Nantong University)

PART ONE

LOCOMOTOR SYSTEM

1

Osteology

The locomotor system is composed of bones, joints as well as skeletal muscles and forms about 60% of the body weight. Bones meet at joints and form a framework to support body weight and protect the body. Skeletal muscles are attached to bones to produce body movements. Bones act as levers, joints as pivots, and skeletal muscles are motion generators.

Section 1 General Description

1. Organization of Skeleton

The science concerned with the study of bones is called **osteology.** Although the number of bones in the adult skeletal system is often reported to be 206 (Fig. 1-1), the actual number varies from person to person depending on the age and genetic factors. At birth, the skeleton consists of about 270 bones. During adolescence, however, the number of bones decreases as separate bones gradually fuse. Approximately half of the bones are in the hands and feet. Each bone is actually an organ that plays a part in the overall functions of the skeletal system. Although individual bones are relatively rigid, the skeleton as a whole is remarkably flexible and allows the human body to have a considerable range of movement.

For convenience of study, the skeleton is divided into axial skeleton and appendicular skeleton. The former refers to the skull as well as the other axial bones of the trunk; the latter refers to the bones of upper limbs and bones of lower limbs as well as the shoulder and pelvic girdles.

2. Classification of Bones

Bones are classified into four groups according to their shapes: long bones, short bones, flat bones, and irregular bones (Fig. 1-2).

(1) Long bones Long bones are longer than their width and are located on the limbs. A typical long bone has two expanded ends and a shaft. The expanded end is called an **epiphysis.** On its outer surface, the articulating portion of the epiphysis is called **articular surface,** which is covered with a layer of cartilage, called **articular cartilage.** The shaft of the bone, which is located between the epiphyses, is called the **diaphysis.** The diaphysis is a rigid tube with a hollow center, called the **medullary cavity.** It also contains small holes called **nutrient foramina** through which blood vessels enter the bone. The portion between the diaphysis and the epiphysis is called the **metaphysis.** In children, there is a band of cartilage located in the metaphysis, called the **epiphysial disc (plate).** A long bone will continue to grow in length as long as cartilaginous cells of the epiphysial cartilage are active. However, once ossification centers of the diaphysis and ephiphysis meet and the epiphysial disc also becomes ossified, forming the so called **epiphysial line,** growth in length is no longer possible at that end of the bone. These ossifications are completed before the age of 25.

(2) Short bones Short bones are somewhat cubelike and exemplified in the wrist and ankle bones. Their main function is the distribution of applied forces.

(3) Flat bones Flat bones are platelike structures with broad surfaces. They contribute substantial parts of the cranial cavity, thoracic cavity and pelvic cavity that protect corresponding organs and body parts, exemplified by calvaria, ribs, and sternum.

(4) Irregular bones Irregular bones, exemplified by vertebrae and many of the facial bones, have a great variety of shapes. Some irregular bones, such as frontal bone and temporal bone, are also called **pneumatic bones,** so named because they contain air-filled cavities.

In addition to these four groups of bones, some authorities allow for a fifth group called **sesamoid bones.** The sesamoid bones develop in response to physical stress, tension, and friction as tendons. Two patellae (knee caps), present almost in everybody, are the largest sesamoid bones in the human body.

3. Structures of Bones

Bone is composed of the osseous tissue, the periosteum, the bone marrow, the blood vessels, lymphatic vessels and nerves (Fig. 1-3).

(1) **Osseous tissue** The osseous tissue is the principal tissue of bones and can be found in two different forms: compact bone and spongy bone. **Compact bone** is solid, strong, and resistant to bend. The outer layers of all bones and the walls of the diaphysis of all long bones are of this type. **Spongy bone** consists of numerous interconnected bony plates and rodes called **trabeculae,** and provide strength. The trabeculae are most developed in the epiphyses that are subjected to forces of compression. In the flat bones of the skull, there is a sandwiched bone between the compact outer and inner layers of compact bones, which are called **diploe.** Due to this organization, a blow to the head may fracture the outer compact bone layer without harming the inner compact bone layer or the brain.

(2) **Periosteum** Periosteum covers the outer surface of bones. It has two layers.

The outer layer is a dense fibrous connective tissue and contains blood vessels as well as nerves. The inner layer mostly consists of a single layer of osteoblasts and a few osteoclasts. Osteoblasts are bone-producing cells whereas osteoclasts are cells responsible for the breakdown and reabsorption in bones. Periosteum has crucial functions in formation and repair of the bone tissue.

The **endosteum** is a membrane that lines the inner surfaces of bone such as the medullary cavity of the diaphysis and the smaller cavities in the spongy bone. Just like the inner layer of the periosteum, the endosteum also consists of a single layer of osteoblasts and osteoclasts.

(3) **Bone marrow** Bone marrow is a soft, gelatious connective tissue found in the cavities of the bones. There are two types of bone marrow, red marrow and yellow marrow. **Red bone marrow** has the precursors of all the blood cells and platelets. At birth until about the age of 7 in humans, bone marrow

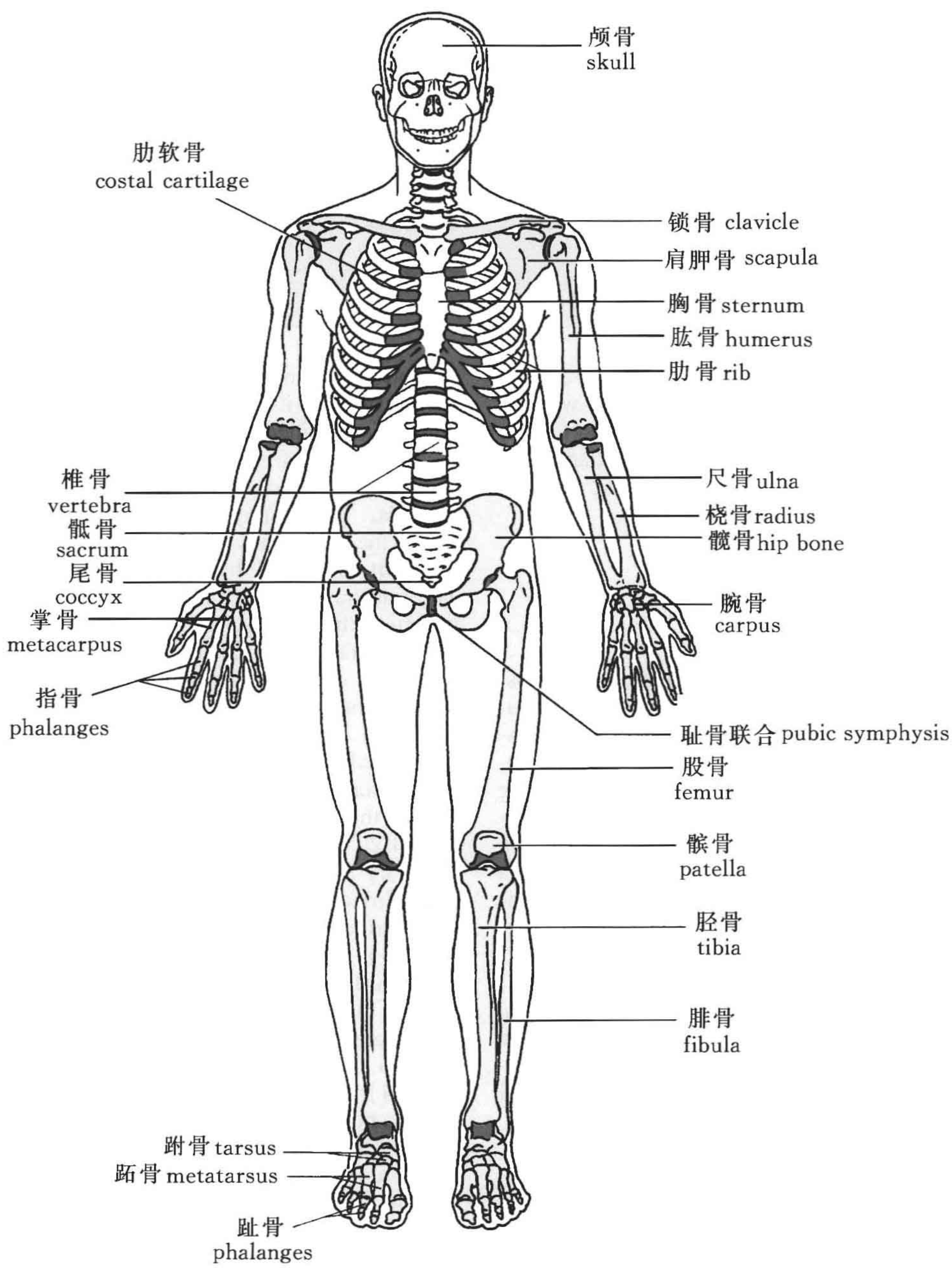

Fig. 1-1 The human skeleton (anterior view)

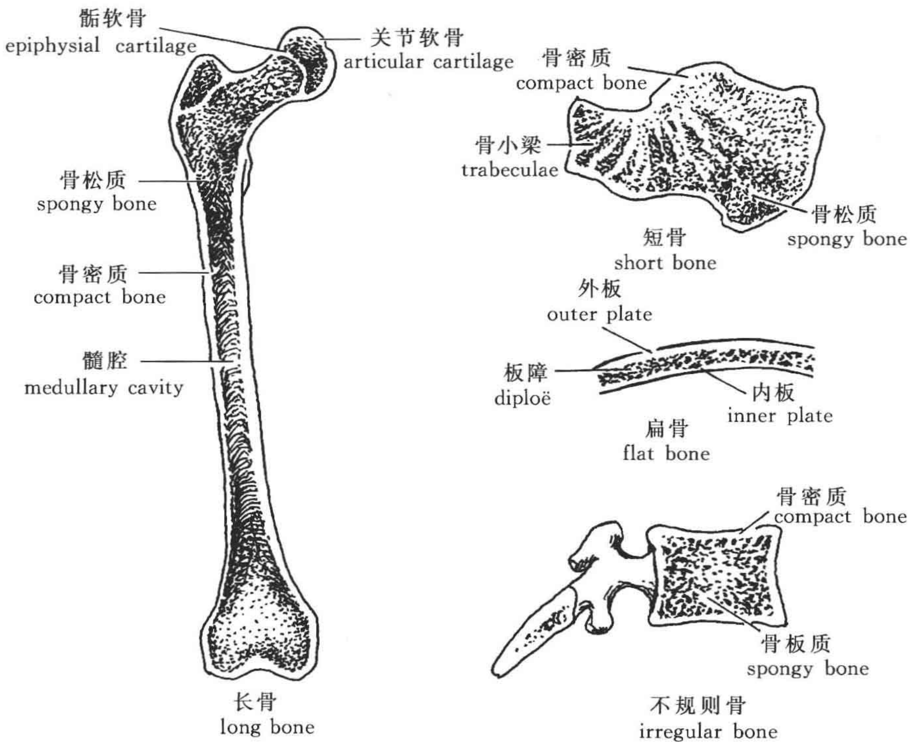

Fig. 1-2 The shapes and structures of bones

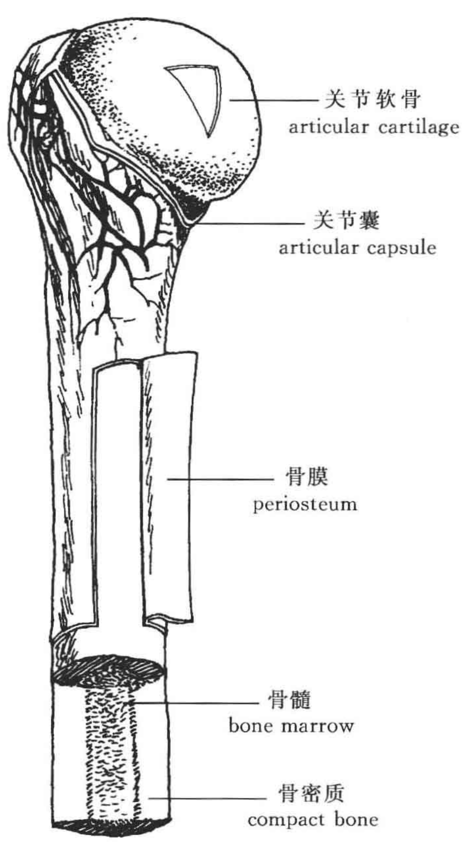

Fig. 1-3 The structures of a long bone

is red in color as there is constant, enormous need for new blood cell formation. With aging, much of the red bone marrow is replaced by yellow bone marrow, which mainly consists of adipose tissue. Yellow bone marrow, on the other hand, does not produce blood cells. In an adult, red bone marrow is found primarily in spongy bones of the vertebrae, iliums, ribs, sternum and the proximal ends of humeruses and femurs. If the blood cell supply is deficient, some yellow bone marrow may change back into red bone marrow as more and more blood cell precursors, red disk in color and responsible for blood cell production, replace yellowish fat cells.

(4) Blood vessels, lymphatic vessels and nerves of bones

1) Blood Vessels: In long bones, blood supply is provided by nutrient arteries, metaphysical arteries and periostial arteries. Nutrient arteries are the principal arteries, which enter into the medullary cavity through the nutrient foramen and then branch into ascending and descending branches to reach the ends of the bone. In irregular bones, short bones and flat bones, periotial arteries or nutrient arteries provide the blood supply. Arteries are accompanied by one and more veins.

2) Lymphatic Vessels: The periosteum is richly supplied by lymphatic vessels; the osseous tissue has probably none.

3) Nerves: Bones are innervated mainly by sensory nerves which enter the bones accompanying the blood vessels, visceral sensory nerves innervate the walls of the blood vessels while somatic sensory nerves innervate the periosteum.

4. Functions of Bones

The bones support and protect body structures while also acting as levers to aid body movements. In addition, they perform the functions such as hemopoiesis and mineral storage.

(1) Support Without the skeletal system, we would have no fixed shape. The skeleton forms a rigid framework to support the mass of muscles and organs, which together may weigh five times as much as the bones themselves.

(2) Protection Bones of the skeleton protect important organs. The skull protects the eyes, ears, and brain. The vertebral column encloses the spinal cord and protects it. The thorax protects the heart and lungs. The pelvic bones support and protect the pelvic viscera.

(3) Movement Bones serve as attachment points for skeletal muscles. In this capacity, bones in combination with joints, act as levers and pivots when muscles contract.

(4) Hemopoiesis The process of blood cell formation is called hemopoiesis. In infants, the spleen and liver produce blood cells, but as the bone matures, the bone marrow takes over this formidable task.

(5) Mineral storage The inorganic matrix of bone is composed primarily of minerals such as calcium and phosphorus. About 95% of the calcium and 90% of the phosphorus within the body are deposited in the bones and teeth. In addition to storing calcium and phosphorus, bone tissue also contains lesser amounts of magnesium, potassium, and carbonate ions.

5. Surface Features of Bones (Anatomical Features of Bones)

Many surface features of bones are based on the relationship between the bones and associated soft tissues. For example, tubercles and projections on bones are usually points of attachment for ligaments or tendons; and, holes in bone, called foramina (singular, foramen) are for blood vessels and nerves to them. Some bones contain epithelial-lined spaces, filled with air, called sinuses.

(1) Nonarticulating Prominences A marked bony prominence is named a **process.** A sharp, slender process is called a **spine.** A large, roughened process is termed a **tuberosity.** A small rounded process is named a **tubercle.** A narrow, ridgelike projection is called a **crest.**

(2) Depressions A large flattened or shallow surface is named a **fossa.** A small shallow surface is called a **fovea or foveola.** A groove that accommodates a vessel, nerve, or tendon is termed a **sulcus.**

(3) Cavities and openings A hollow space in a bone is

called a **cavity.** A small cavity is termed a **cellule.** Air-filled cavities located in the facial bones are called **sinuses.** A long passage is termed a **canal** or **meatus.** A rounded opening through a bone is named a **foramen or aperture.** An irregular opening is called **hiatus.** A narrow slitlike opening is termed a **fissure.**

(4) Expanded ends A prominent, rounded articulating end of a bone is named the head or capitulum. Inferior to the head, the narrow part is called the neck. A large, rounded articulating knob is termed the condyle. A projection on the condyle is named the epicondyle.

6. Chemical Composition and Physical Properties of Bones

The bone matrix consists of organic material and inorganic material. The major organic components are collagen and mucopolysaccharide, which act like reinforcing steel bars and lend flexible strength to the bone matrix. The major inorganic components are minerals, mainly calcium phosphate, which acts like concrete and gives the bone matrix compression strength.

If all the minerals are removed from a long bone, collagen becomes the primary constituent, and the bone becomes very flexible (Fig. 1-4). On the other hand, if the collagen is removed from the bone, the mineral components become the primary constituents, and the bone becomes very brittle.

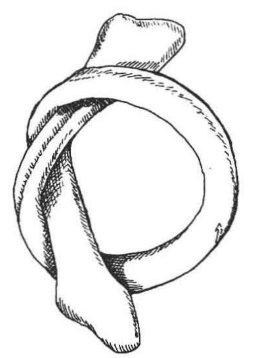

Fig. 1-4 The demineralized bone

7. Development and Growth of Bones

Bones are derived from the mesenchyme of the embryonic mesoderm. Some bones originate within sheetlike layers of connective tissues; the process of forming the bone by replacing connective tissue is named the intramembranous ossification. Others begin as masses of cartilage that are later replaced by bone tissue; this process is called the endochondral ossification.

(1) Intramembranous Ossification The broad, flat bones of the skull are developed by intramembranous ossification. At the site where these bones develop, sheets of primitive connective tissues appear. The primitive cells located in the primitive connective tissues get organized around the blood vessels. They enlarge and differentiate into the **osteoblasts,** which, in turn, deposit bony matrix around themselves. As a result, spongy bone forms in all directions. Later, the osteoblasts become osteocytes when bony matrix completely surrounds them. The spot beginning to form the bone is called **centers of ossification.** The cells of the primitive connective tissue that stays outside the developing bone form the periosteum. Osteoblasts on the inside of the periosteum form a layer of compact bone over the surface of the newly formed spongy bone.

(2) Endochondral Ossification Most of the bones of the skeleton are developed by endochondral ossification. Firstly, mesenchymal cells become chondrocytes, surrounded by cartilage matrix, and form the hyaline cartilage models of the future bones. Then blood vessels invade the perichondrium surrounding the cartilage model, osteochondral progenitor inside cells within the perichondrium change into osteoblasts producing the compact bone **bone collar** on the surface of the cartilage model, while the perichondrium becomes the periosteum. Meanwhile, the cartilage model gets larger in size and its central part begins to change into calcified cartilage. Blood vessels and undifferentiated connective tissue cells as well as some osteoblasts and osteoclasts move into the calcified cartilage. These osteoblasts and osteoclasts begin to form the bone. This area of bone formation is called the center of **primary ossification.** Osteoclasts' main function is to from the center of the cartilage model to form the medullary cavity.

In long bones, the diaphysis is the primary ossification center, and the other sites of ossification are called **secondary ossification** centers that develop in the epiphyses. The processes forming the bone at the secondary ossification centers are the same as that at the primary ossification centers, with the exception of medullary cavity formation. Primary ossification centers start developing early in the fetal development, whereas secondary ossification centers show up around 1 month before birth.

Section 2 Axial Bones of the Trunk

Axial bones comprise 24 separate vertebrae, 1 sacrum, 1 coccyx, 1 sternum, and 12 pairs of ribs.

1. Vertebrae

In an infant, there are thirty-three separate vertebrae. With the increasing age, however, the final four individual vertebrae fuse to form the coccyx, and five individual vertebrae superior to them eventually fuse to form the sacrum. As a result, in an adult, there are 24 separate vertebrae, 1 sacrum, and 1 coccyx. These bones and their joints form the vertebral column, or spinal column. These 24 separate vertebrae are named according to where they are located: cervical vertebrae(7), thoracic vertebrae (12), and lumbar vertebrae(5). Although they all have regional specifics, some of their characteristics are common.

(1) General structures of vertebrae A typical vertebra consists of a **vertebral body** and a **vertebral arch** as well as some processes (Fig. 1-5). The vertebral body is the weight-bearing part. It is a drum-shaped structure and has flat upper and lower surfaces, forming the anterior portion of the vertebra. The vertebral arch is attached to the posterior surface of the body and is composed of two **pedicles of vertebral arch** together with two **laminae of vertebral arch.** The pedicles of vertebral arch are short stalks projecting posteriorly from the vertebral body. On the inferior and superior margins of the vertebral pedicles are notches that align to form openings, which are called **intervertebral foramina.** Intervertebral foramina provide passageways for thoracic and lumbar spinal nerves. The **laminae of vertebral arch** are plates, which arise from the pedicles to fuse in the back to become a **spinous process.** On the junction between the pedicle and lamina are three kinds of processes: projecting laterally are two **transverse processes;** projecting superiorly are two **superior articular processes;** and projecting inferiorly are two **inferior articular processes.** The spinous process and transverse process serve for muscle attachment.

The vertebral body and the vertebral arch enclose a large opening called **vertebral foramen.** 24 separate vertebral foramina connect in series to form the vertebral canal. The vertebral canal contains the spinal cord together with some adipose tissue, connective tissue, and blood vessels.

(2) Regional characteristics of vertebrae

1) Cervical vertebrae: The seven cervical vertebrae (Fig. 1-6) are distinguished by the presence of a **transverse foramen** in each transverse process, which provides a passageway for the vertebral artery with the accompanying vein and nerve. The vertebral body is small, and broader from side to side than from front to back. Its superior surface presents upward projecting lips on each side, which are called **unci of the vertebral body;** they form **Luschka joints** with the anterior and posterior projecting lips of the adjacent vertebrae. The articular surfaces

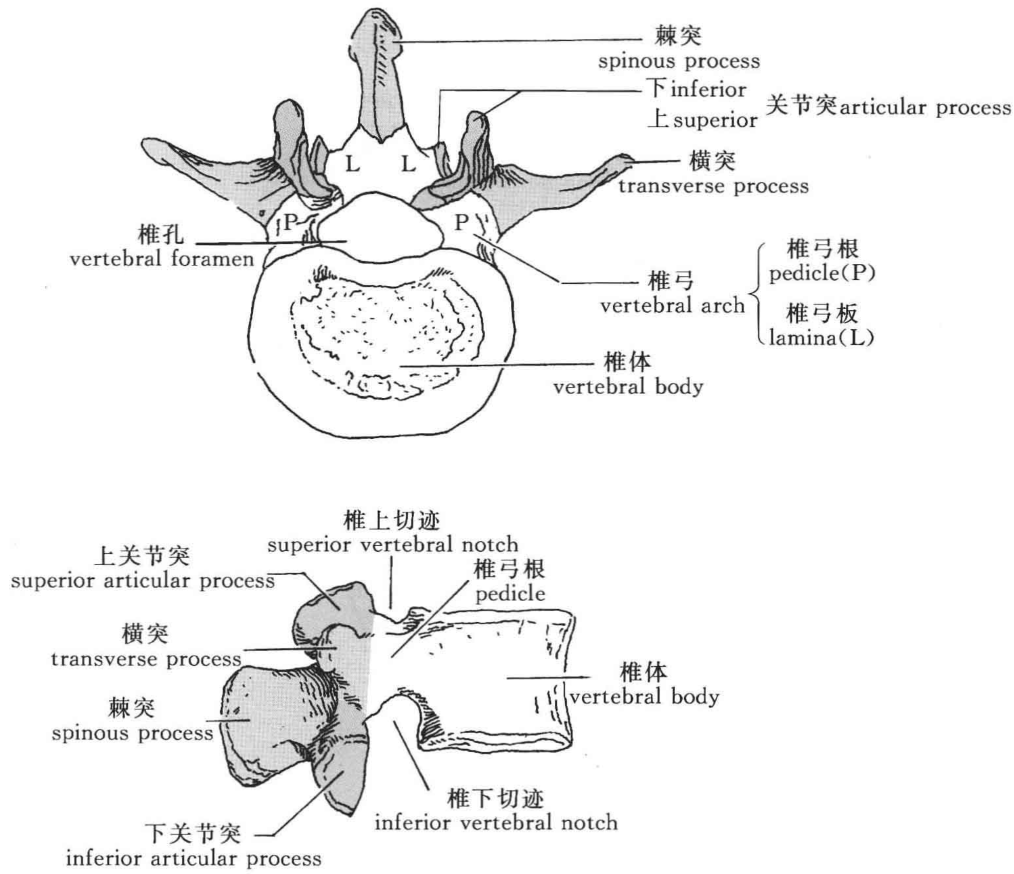

Fig. 1-5 The general structure of vertebrae

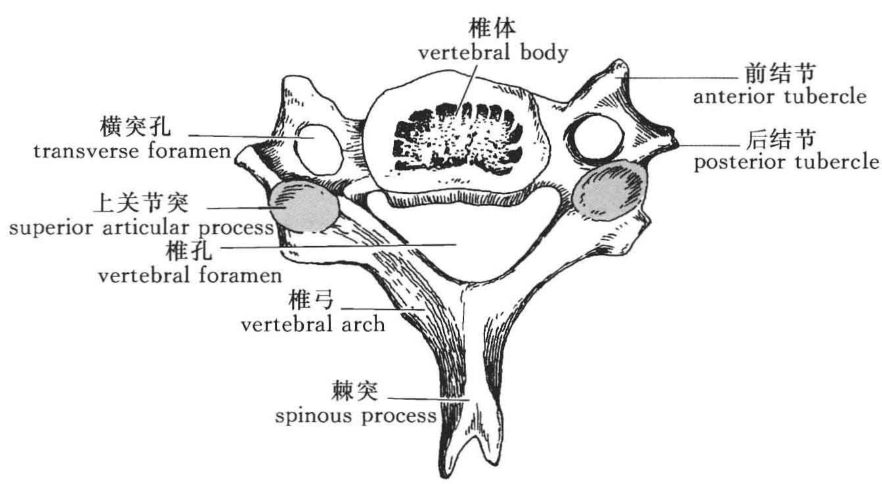

Fig. 1-6 The cervical vertebra(superior view)

located on the superior and inferior articular processes are quasi-horizontal. The vertebral foramen is larger than inferior foramina and is triangular in shape. The spinal processes are bifid except the first and the seventh cervical vertebrae. The cervical vertebrae form a flexible framework for the neck and support the head.

The first cervical vertebra is also called **atlas**(Fig. 1-7). It has no vertebral body, but has anterior arch and posterior arches as well as two lateral masses. On the posterior surface of anterior arch, the atlas has a **dental fovea** which articulates with the dens of axis. On the superior surfaces of the lateral masses, the atlas has two kidney-shaped articular surfaces, articulating with the occipital condyles. The posterior arch is much longer than the anterior arch and has a **groove-**posterior to the superior articular process-for vertebral artery.

The second cervical vertebra is also called **axis** (Fig. 1-8), and has peglike dens called the **dens of axis.** The dens of axis articulates with the dental fovea to form the median atlantoaxial joint.

The seventh cervical vertebra is called **vertebra prominens** (Fig. 1-9), which has an elongated spinous process that is easily felt at the posterior base of the neck and is commonly used as a clinical landmark to locate a particular vertebra accurately.

2) Thoracic vertebrae: The twelve thoracic vertebrae (Fig. 1-10) have **superior and inferior costal foveas** on the sides of the vertebral bodies, which articulate with the costal heads, and **transverse costal fovea** on the transverse processes, which articulate with the costal tubercles except for the last two ones. The vertebral body increases in size from superior to inferior. Its transverse surface is heart-shaped. Each thoracic vertebra has a long spinous process, which slopes obliquely downwards to overlap the spinous process of the inferior thoracic vertebra, just like tiles are laid to overlap each other.

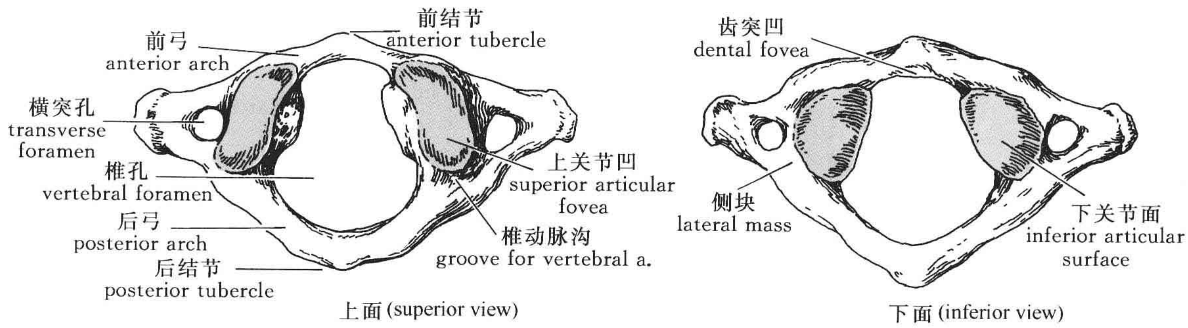

Fig. 1-7 The atlas

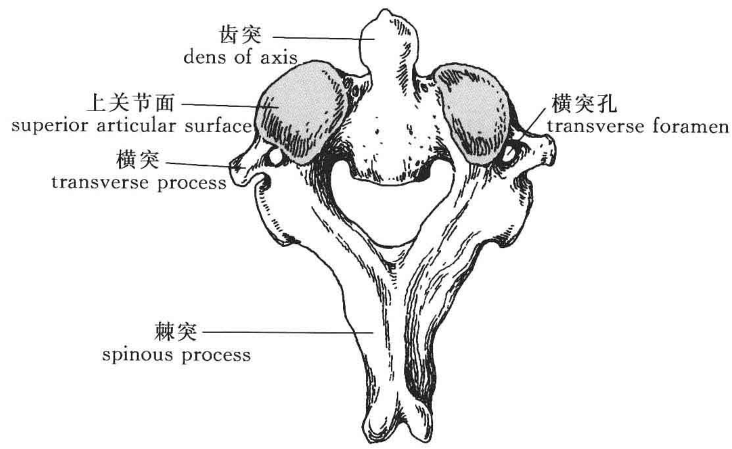

Fig. 1-8 The axis

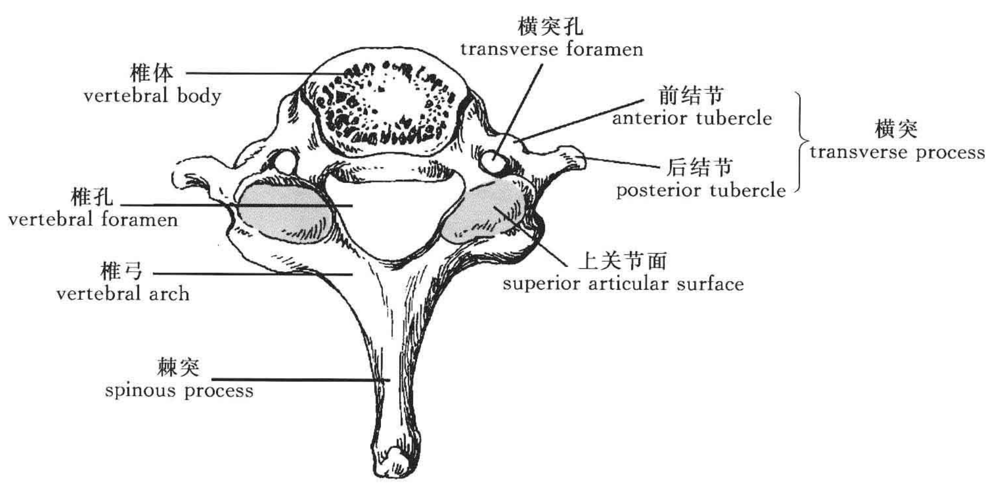

Fig. 1-9 The vertebra prominens

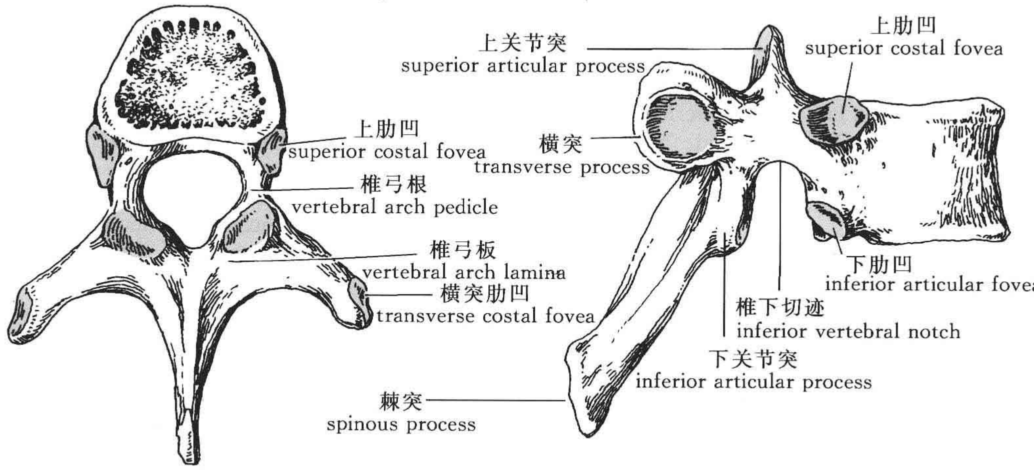

Fig. 1-10 The thoracic vertebrae