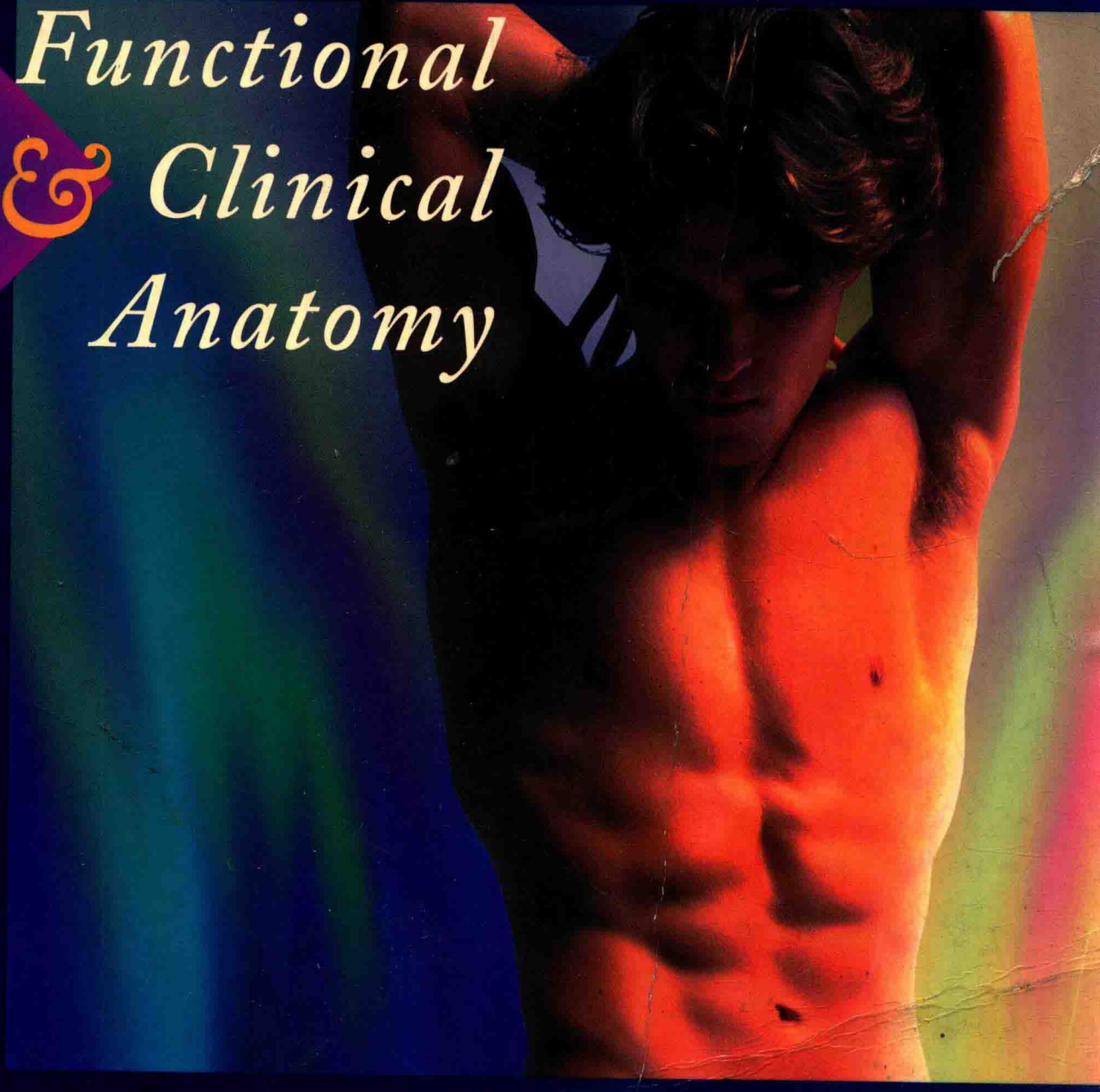
McMinn's Functional & Clinical Anatomy



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Mosby

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PREFACE

The object of this book is to provide an account of body structure and function for those who are entering the health care professions. The account of body anatomy and physiology is enlivened by reference to common diseases and injuries that are so often seen as part of the daily routine by those involved in health care. The purpose of bringing clinical material to this early stage of learning is not to teach clinical details, but simply to introduce to students commonly used medical terms and to explain their anatomical and physiological backgrounds, in order to emphasize how necessary a knowledge of normal form and function is for understanding what happens when things go wrong. Heart transplants may hit the headlines, but varicose veins and hernias, coronary artery disease and diabetes, gallstones and fractures of the wrist are the stuff of everyday medical practice with which all medical and paramedical attendants must become familiar, and this is why we have used such common conditions for illustrating the application of basic science to clinical problems. Our aim has been to be informative but concise, and we make no apology for having been selective and for not trying to drag in every possible detail. The background to many standard procedures commonly carried out by nurses and doctors is also included to add interest and relevance to learning, by showing how knowledge of what often appear to be dull facts is put to practical use in patient care.

The first part of the book summarizes the tissues and the various body systems, and this is followed by adding further details on a regional basis. This plan has been chosen because, although the function of body systems as a whole has to be appreciated, patients usually have something wrong with a particular organ or area, or need attention to a particular organ or area, and this is what has to be tackled by their attendants. This may not be the usual approach to basic science teaching but we believe it is a practical one that will add to student understanding and interest (and to stimulate interest instead of boring the pants off readers is always one of the problems of teaching basic sciences, which often seem remote from practical problems). We hope our presentation will be just such a stimulus and will lead to a desire for further study.

Despite the need for a sound background in basic sciences, those responsible for looking after patients should remember that there will always be times when a kind word, and the gentle touch that says 'I care', are more important than all the latest technological advances.

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Penelope Gaddum–Rosse
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We would also like to thank Roddy Craig of Mosby, who was left holding many editorial babies and reared them successfully.

CONTENTS

CHAPTER 1

ANATOMICAL TERMS AND DESCRIPTIONS

PARTS OF THE BODY

The **body** (**1.1a**) is made up of the head, trunk and limbs. The **trunk** consists of the **neck**, the **thorax** (i.e. the chest), and the **abdomen** (the belly). The lower part of the abdomen is the **pelvis**, but this word is also used to refer to the bones of the pelvis. The lowest part of the pelvis – and hence the lowest part of the trunk – is the **perineum**. The central axis of the trunk is the **vertebral column** (the spinal column or spine), and the upper part of it (the cervical part or cervical spine) supports the **head**.

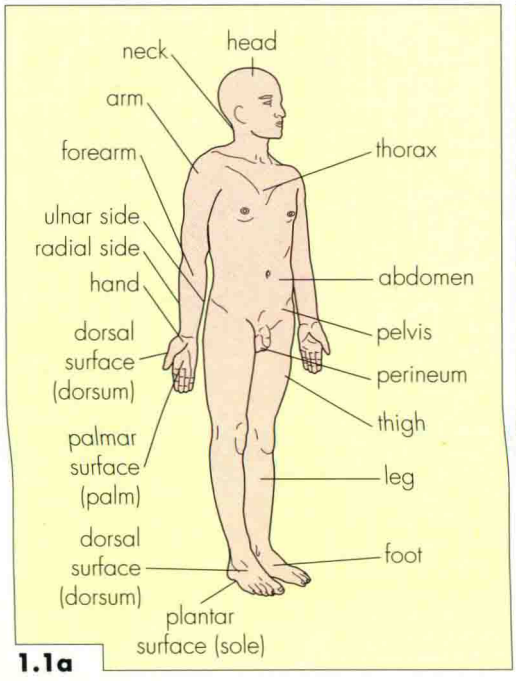
The main parts of the **upper limb** are the **arm**, **forearm** and **hand**. Note that in strict anatomical terms the word 'arm' means the upper arm, between the shoulder and elbow, although the word is commonly used to mean the whole of the upper limb.

The main parts of the **lower limb** are the **thigh**, **leg** and **foot**. The word 'leg' strictly means the part between the knee and foot, but is commonly used to mean the whole of the lower limb.

DESCRIPTIVE TERMS

For the description of the positions of structures, the body is assumed to be standing upright with the feet together and the head and eyes looking to the front, with the arms straight by the sides and the palms of the hands facing forwards (**1.1a**). This is the *anatomical position*, and structures are always described relative to one another using this standard position, even when the body is, for example, lying in bed or on a dissecting room table (or even when standing on its head!).

To the student who is new to the subject, many of the anatomical terms described below will seem strange at first sight, but every subject has its own jargon, and anatomy is no exception. When necessary, reference should be made back to the following paragraphs when reading the later text; there is no need to memorize every definition at this stage, since continued use will soon make the meanings clear and familiar.



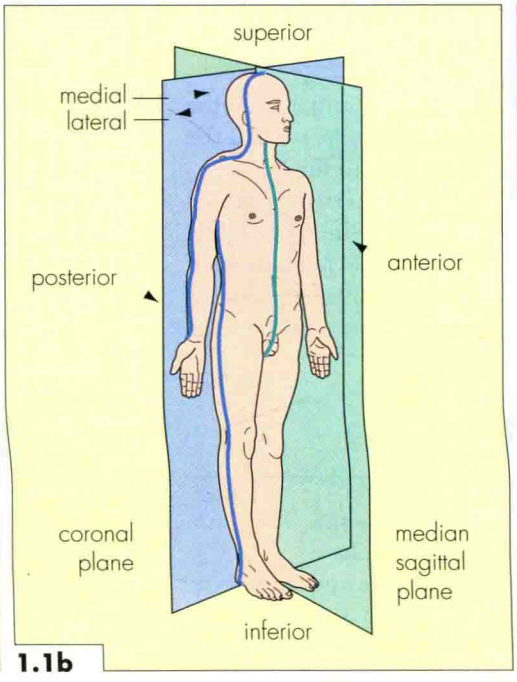


Fig. 1.1 Parts of the body.
(a) Parts and surfaces
(b) Descriptive adjectives and planes

The *median sagittal plane* is an imaginary vertical, longitudinal plane through the middle of the body from front to back, dividing the body into the right and left halves (**1.1b**). The adjective *medial* means nearer the median plane, and *lateral* means farther from it. Thus, in the anatomical position, the little finger is on the medial side of the hand and the thumb is on the lateral side; the great toe is on the medial side of the foot and the little toe on the lateral side.

In the forearm, where there are two bones, with the radius on the lateral (thumb) side and the ulna on the medial side, the adjectives *radial* and *ulnar* can be used instead of lateral and medial. Similarly, in the lower leg, where there are two bones, with the fibula on the lateral side and the tibia on the medial side, the adjectives *fibular* and *tibial* are sometimes used.

Anterior and *posterior* mean 'nearer the front' and 'nearer the back' of the body respectively (**1.1b**). Thus, on the face, the nose is anterior to the ears (more strictly, anteromedial) and the ears are posterior to the nose (more strictly, posterolateral). Sometimes *ventral* is used instead of anterior, and *dorsal* instead of posterior; these are terms from comparative anatomy that are appropriate for four-footed animals.

The hand and foot have special terms applied to them. The anterior or ventral surface of the hand is usually called the **palm** or palmar surface, and the posterior or dorsal surface is the **dorsum**. In the foot, however, the upper surface is the dorsal surface or dorsum and the under surface, or **sole**, is the plantar surface.

Superior and *inferior* mean nearer the upper or lower end of the body respectively (**1.1b**); the nose is superior to the mouth and inferior to the forehead (even if the body is upside down; the upright anatomical position is always the reference position).

Superficial means near the skin surface, and *deep* means farther away from the surface.

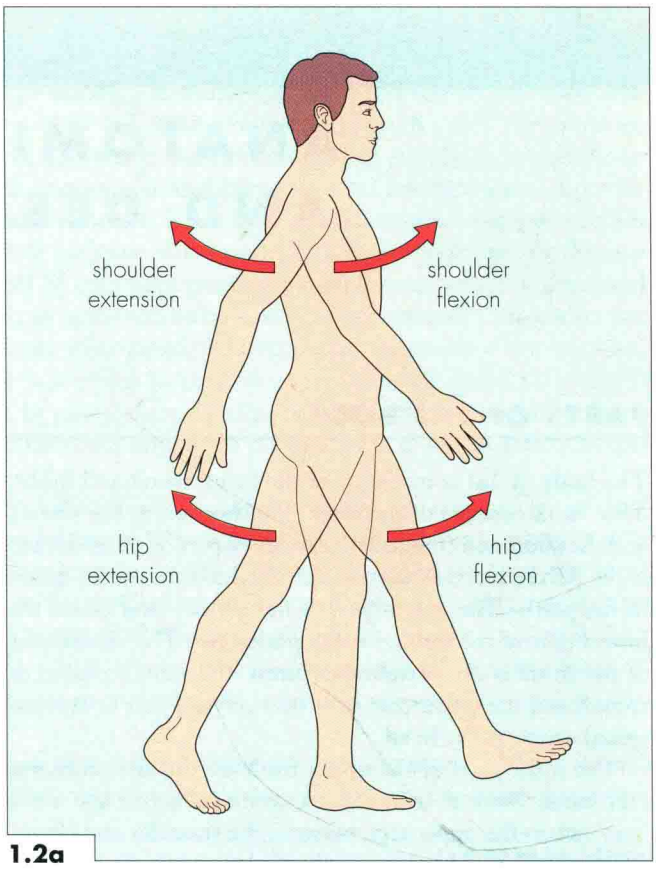
Proximal and *distal* mean nearer to and further from the root of the structure respectively; in the upper limb, the forearm is distal to the elbow and proximal to the hand.

The words *sagittal* and *coronal* describe certain planes of section, most often used in the head and brain. The *sagittal plane* is any front-to-back plane that is parallel to the median plane, and the *coronal plane*, sometimes called the *frontal plane*, is a vertical plane at right angles to the median plane (**1.1b**).

MOVEMENTS

Other terms are used to describe movements. They are defined below and many are illustrated in **1.2a**–r.

Flexion means bending or decreasing the angle between bones, as in bending the elbow; this can also be described as 'flexion of the elbow', 'flexion of the elbow joint', or 'flexion



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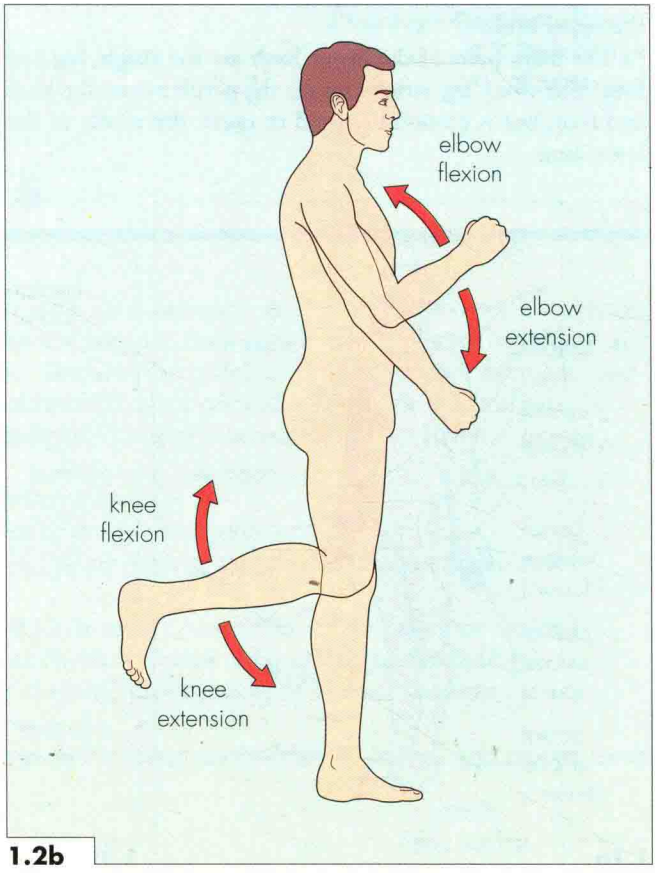

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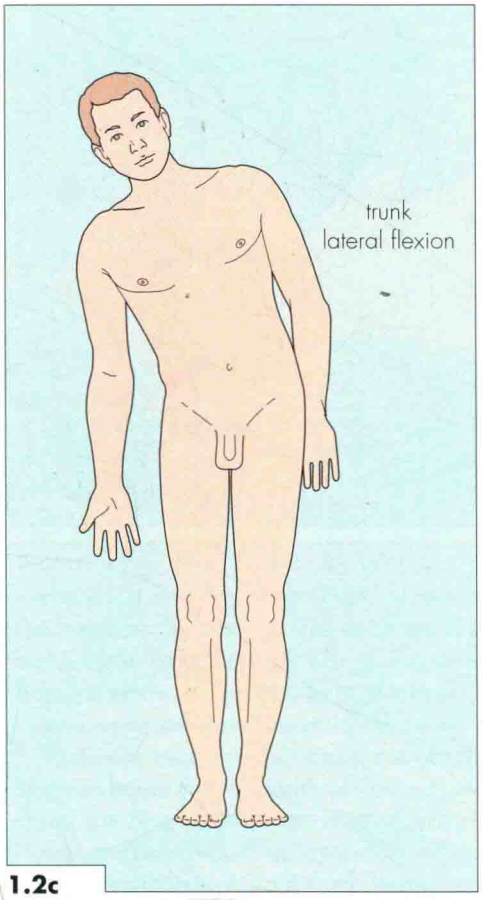

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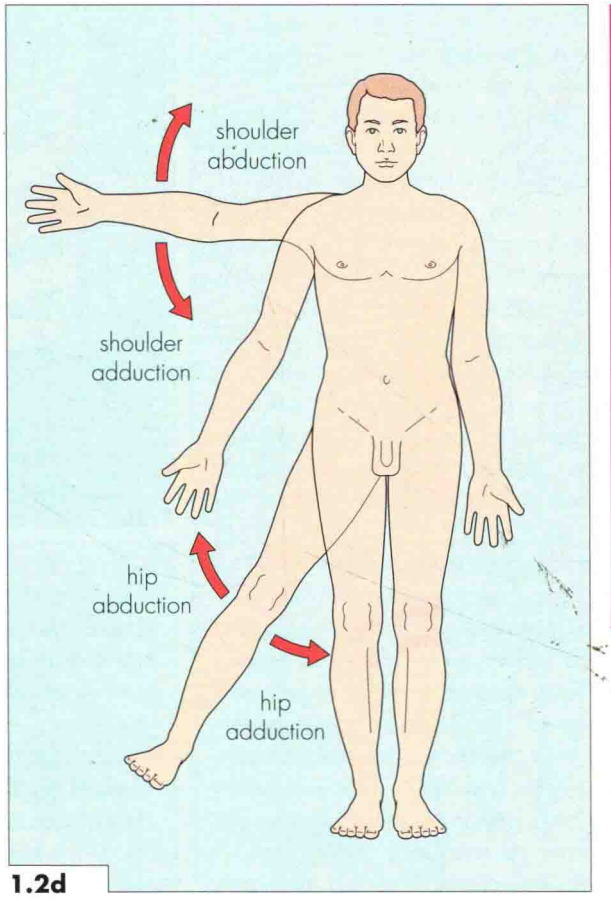
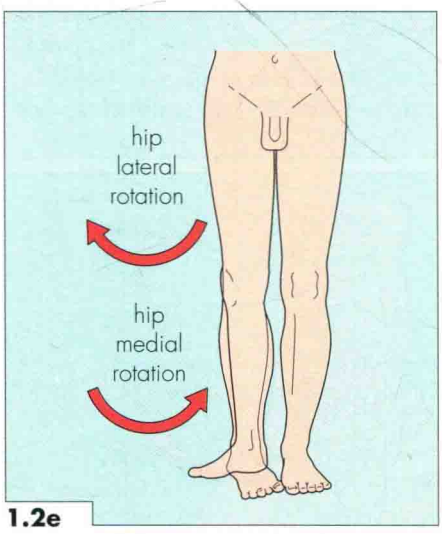


1.2d

Fig. 1.2 Descriptive terms for body movements.
(a) Shoulder
(b) Elbow, knee
(c) Trunk
(d) Shoulder, hip
(e) Hip
(f) Shoulder
(g) Shoulder
(h) Forearm
(j) Forearm
(k) Wrist
(l) Wrist
(m) Fingers
(n) Finger
(p) Ankle
(q) Foot
(r) Toe



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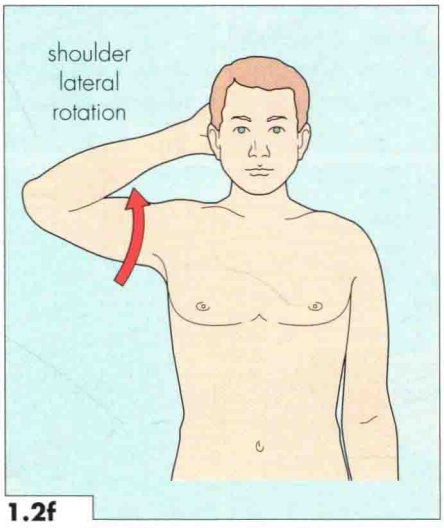

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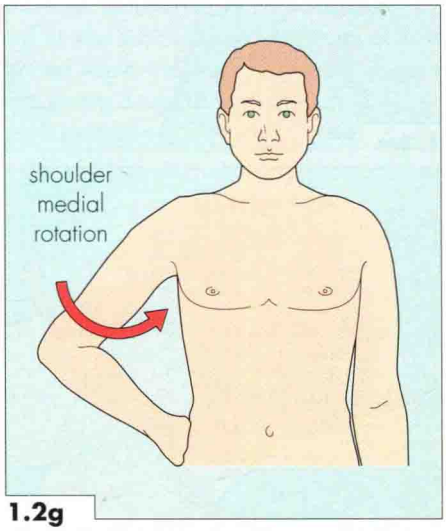

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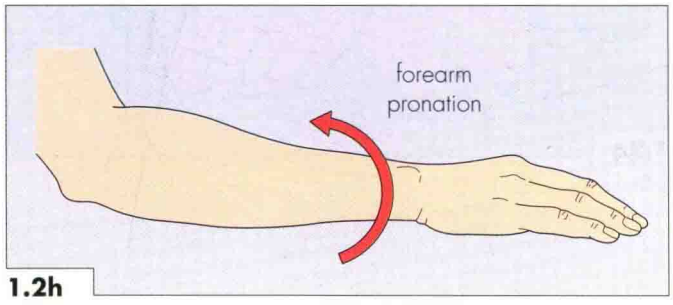

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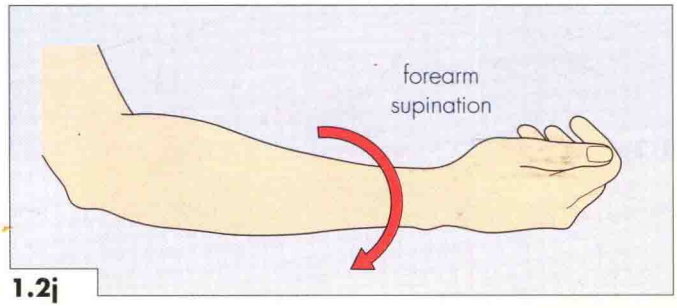

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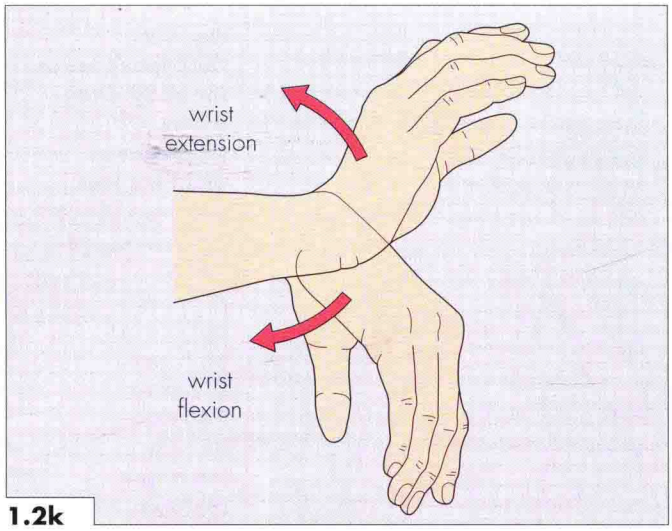

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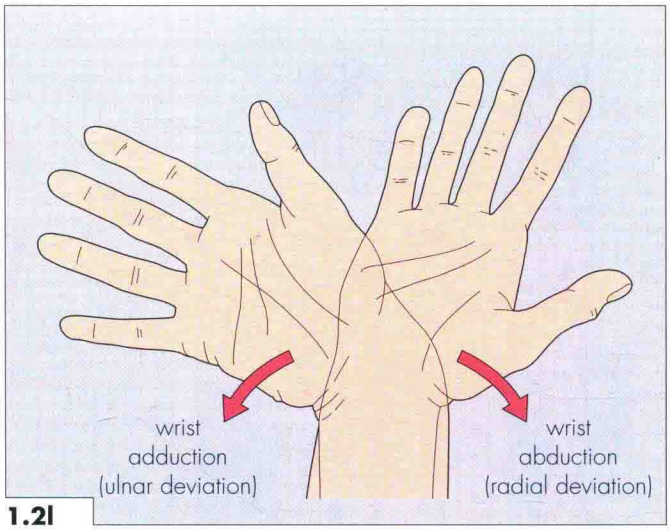

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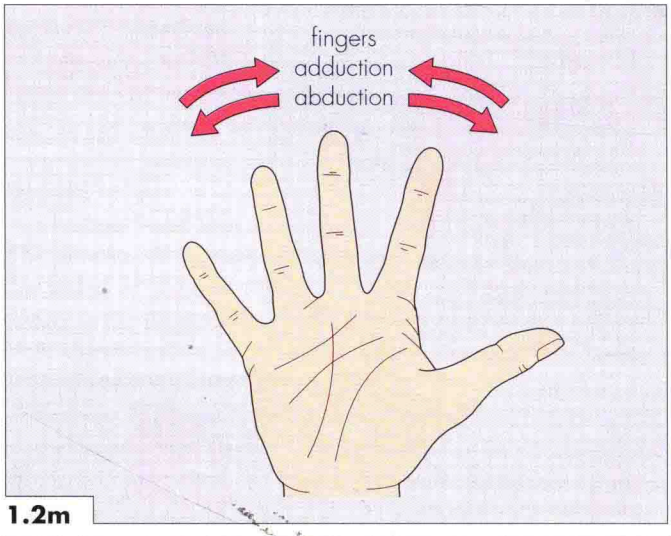

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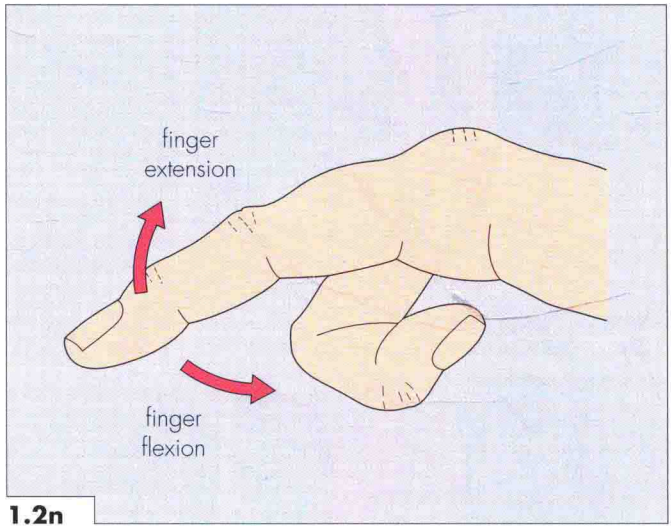

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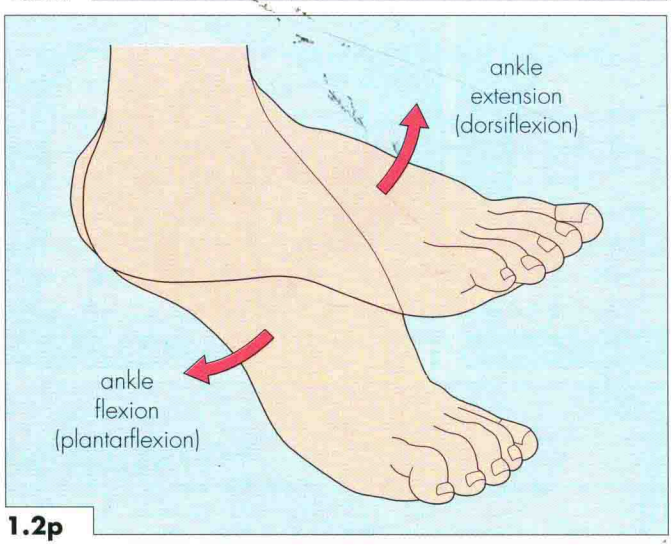

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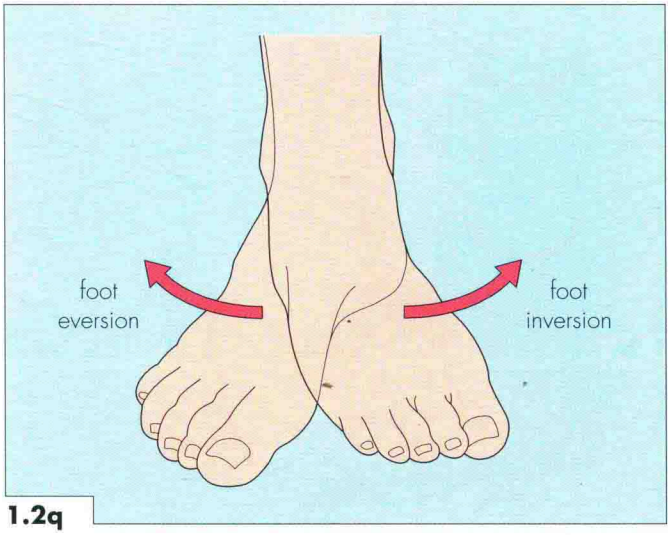

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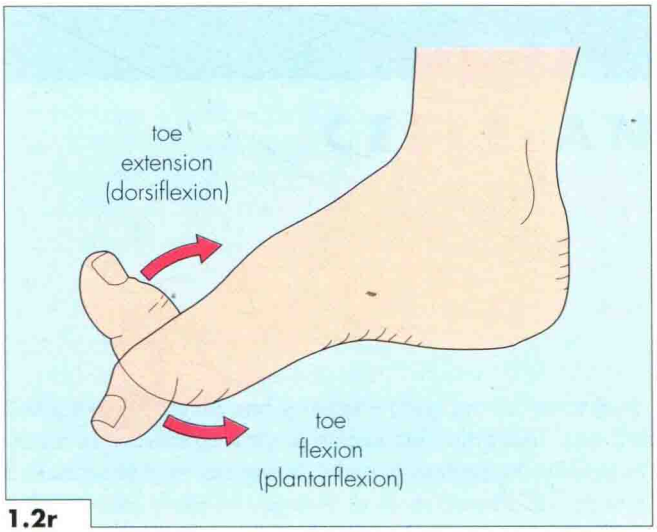


1.2r

of the forearm at the elbow joint'. Flexion can be applied to the trunk of the body as well as to the limbs; bending the trunk forwards is 'flexion of the spine or vertebral column'. Bending sideways (but still facing forwards, without twisting sideways or rotation) is 'lateral flexion'.

Extension means straightening out or increasing the angle between bones (the opposite of flexion), such as in straightening the flexed elbow, or, equivalently, 'extension of the elbow or elbow joint', or 'extension of the forearm at the elbow'. Straightening up the trunk from the flexed position, or bending backwards from the upright position, is 'extension of the spine'.

Abduction is movement away from the midline of the body, as in lifting the arm away from the side at the shoulder, which is described as 'abduction of the shoulder or shoulder joint', or 'abduction of the arm at the shoulder joint'.

Adduction is the opposite of abduction, or movement towards the midline, as when bringing the abducted arm back to the side.

Circumduction is not a term commonly used, but is a combination of the above four movements carried out in sequence, as at the shoulder or hip. In circumduction of the shoulder the hand is made to go round in a wide circle.

Rotation is a twisting movement in the long axis of a bone, applied particularly to the humerus and femur, and can occur in lateral (outward) and medial (inward) directions. Lateral rotation of the humerus, often called 'lateral rotation of the shoulder or shoulder joint', is best illustrated by putting the hand behind the head (which also of course involves abduction of the shoulder and flexion of the elbow). The humerus is medially rotated in putting the hand behind the back.

Pronation and *supination* are terms applied to the forearm. The anatomical position is one of supination, with the radius and ulna parallel; in pronation the lower end of the radius rotates across the lower end of the ulna, turning the palm over. Supination from the pronated position 'untwists' the radius, making it parallel to the ulna again. Many actions of everyday life are carried out with the forearm in the 'mid-prone position' – halfway between full pronation and full supination, as when holding a cup or pencil.

Inversion and *eversion* are terms applied to the foot. In inversion, the inner (medial) border of the foot is raised so that the sole is tilted to face medially. In eversion, the lateral border is raised so that the sole is tilted laterally. These movements are illustrated when walking transversely across a slope: one foot will be inverted and the other everted.

CHAPTER 2

CELLS AND TISSUES

Cells, tissues, organs and systems – these are the units from which all vertebrate animal bodies are composed, and the human body is no exception. Many thousands of millions of **cells** become grouped together to form **tissues**, and tissues combine in varied ways to form structures such as bones, muscles and **organs**. (The stomach, kidneys, lungs, etc., are often collectively called **viscera**, from the plural of the Latin *viscus*, meaning an internal organ.) Organs, in turn, become grouped together into **systems**, each with a particular role to play in keeping the body alive.

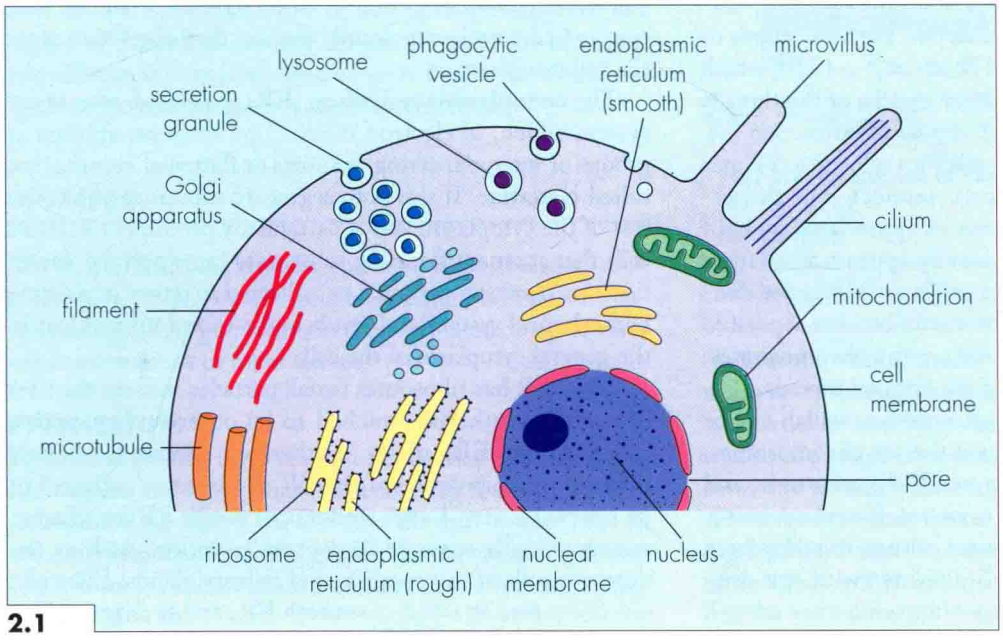
Human life depends upon taking in oxygen and food, which can be broken down into the substances that the body must use in order to provide the necessary chemical energy for maintaining bodily structure and function.

CELL STRUCTURE

The fundamental unit of life is the **cell** (**2.1**). All cells have a **cell membrane** (i.e. a **boundary membrane**) that serves to contain the **cytoplasm**, which is the internal material in which the **nucleus** and the other components – the **organelles** – of the cell lie. Certain organelles are common to most cells, and each organelle has a specific role to play within the cell.

In the very earliest developing embryos, where one original cell becomes two, then four, eight, sixteen etc., all of the cells are similar. Soon, however, they develop into different kinds; some become muscle cells, others become nerve cells, epithelial cells or connective tissue cells – these are the cells that make up the four basic tissue types (see below).

Each type of cell differs from others in function because certain kinds of organelles are predominant; in muscle cells there are masses of filaments that cause contraction, in secretory cells there is a predominance of the organelles concerned with manufacturing the secretory product, and so on. The chemical influences that determine cell type are derived from the cell's genetic material, which is contained in the nucleus; the nucleus is the most obvious structural feature of most cells when they are examined microscopically. The 'messages' that the nucleus sends out to the cytoplasm determine which kind of cell it is going to be. Although the total genetic mate-



2.1

Fig. 2.1 Diagrammatic representation of parts of the cell, as seen with the electron microscope.

rial is identical in every cell of any one individual, only a small part of the vast number of possible messages becomes effective in any one cell, and the message depends upon which **genes** become *expressed* (i.e. activated). The control of gene expression is one of the major fields of research in cell biology today.

CELL MEMBRANE

The **cell membrane** – also known as the **plasma membrane** or **plasmalemma** – controls what enters or leaves the cytoplasm. Cell membranes contain lipids, protein and carbohydrate components, with lipid molecules being particularly numerous.

Certain substances can pass into (or out of) cells, either through minute pores (also called *channels*) in the membrane, or by becoming attached to some of the membrane's 'carrier' molecules which transport the substance across the membrane. Larger particles, such as bacteria, can be 'taken into' some cells through their becoming engulfed in a pocket of membrane which then breaks away from the surface to lie free within the cell as a membrane-bound package called a **vesicle**; this is the process of *phagocytosis* (from the Greek meaning 'cell eating'). *Exocytosis* is phagocytosis 'in reverse'; it is the process of cell secretion, allowing the liberation from the cell of substances manufactured within it.

NUCLEUS

The **nucleus** is a membrane-bound structure, with the enclosed material being called the **nucleoplasm**. The **nuclear membrane**, which is the boundary of the nucleus, is double-layered, with numerous pores that allow substances to pass between the nucleoplasm (inside) and the cytoplasm (outside).

In most cells, the genetic material, which is called DNA (deoxyribonucleic acid), is in the form of extremely fine, tangled **chromatin threads**; if stretched out, the total length of the threads in each nucleus would be about 2 m (7 ft), which seems unbelievable, but is true. Short lengths of the threads constitute the genes, each of which acts as an instruction (i.e. a genetic code) to the chemical machinery of the cell and causes the production of a particular product. The thread-like nature of the chromatin cannot be appreciated by light microscopy, where the nucleus usually appears as a rather darkly staining mass. Only as the cell is preparing for division – called *mitosis* – does the chromatin become separated out into recognizable clumps; these are the **chromosomes**, which are bunched-up versions of the original threads.

In human cells there are 46 chromosomes, which can be arranged into 23 pairs; one pair are the sex chromosomes, designated X and Y; females have two X chromosomes, and males have one X and one Y. To examine chromosomes it is necessary to grow some cells in tissue culture, to make them divide, and then to stop the cell division (with the drug colchicine) to 'capture' the chromosomes while they are still condensed and, therefore, visible microscopically. The tissue is then examined under the microscope and the chromosomes photographed for identification; the process is known as *karyotyping*. Each pair of chromosomes has a characteristic size and shape, and has been given an identification number (1–22); the twenty-third pair are the sex chromosomes. Certain inherited diseases are known to be associated with defects in particular chromosomes (e.g. cystic fibrosis, where there is a defect in chromosome 7), and the total numbers of chromosomes may also be abnormal (as in most cases of Down's syndrome, with three of chromosome 21, known as trisomy 21).

So-called 'DNA fingerprinting' depends on the sequence of amino acids that make up an individual's DNA and, although not quite as unique as a fingerprint, has forensic use for identification from cells in mere fragments of tissue or secretions such as saliva or semen. The discovery that there is some DNA in mitochondria which is inherited only by females is of great interest for long-term genealogical studies.

ORGANELLES

Apart from the nucleus, various other structural components of the cell are found in the cytoplasm. The most important are considered below; many have membranes as part of their structure.

Mitochondria are rounded or sausage-shaped structures which, because of their capacity to generate ATP (adenosine triphosphate, p.83), are responsible for meeting the energy requirements of the cell. When ATP is broken down, a large amount of energy is made available, thus enabling the cell to undertake many other chemical reactions. Mitochondria have therefore been called the 'powerhouses' of the cell.

Lysosomes are membrane-bound packages of enzymes that can join up with phagocytic vesicles so that the enzymes can break down (i.e. digest) the engulfed material into smaller and harmless molecules that are then allowed to enter the cell cytoplasm.

The **endoplasmic reticulum** (**ER**) is a closed-membrane system which, in electron microscope sections, appears as groups of interconnecting channels or flattened sacs that are called **cisternae**. It serves to segregate substances from the rest of the cytoplasm, and is particularly prominent in those cells that are manufacturing substances for export, i.e. secretion. Such substances must be collected together in a membrane-bound system and not become mixed up and lost in the general cytoplasm of the cell.

Some ER has ribosomes (small particles that are the sites of protein synthesis) attached to its outer surface, and is called **rough ER**; newly synthesized proteins can pass through the membrane of the ER and become collected in its internal cavity. Large amounts of rough ER are characteristic of cells engaged in protein secretion, such as the digestive cells of the pancreas and salivary glands. ER without ribosomes attached is **smooth ER**, and is characteristic

of cells engaged in the secretion of steroid hormones, such as those of the adrenal cortex.

While ribosomes occur frequently in association with the ER (as mentioned above), they also occur in an 'unattached' form; these are **free ribosomes**. In this case, they function in the synthesis of proteins to be used inside the cell, rather than to be exported.

The **Golgi apparatus** (also called the **Golgi complex**) is another membrane system, appearing as a collection of elongated sacs and vesicles. It is prominent especially in many secretory cells, for it receives substances from the rough ER, perhaps concentrating them or modifying them chemically, and then forming membrane-bound vesicles of secretory product – called **secretion granules** – that migrate to the apex of the cell and fuse with the boundary membrane, so liberating the secretory material from the cell.

On the surfaces of many cells are numerous small, rod-like projections of the cell membrane; they have an internal core of cytoplasm. These **microvilli** increase the surface area of the cell, and are particularly numerous in cells whose main function is absorption, such as the epithelial cells of the small intestine and in certain kidney tubules.

In the respiratory tract there are many cells whose surfaces bear numerous hair-like processes or **cilia**. They are larger than microvilli and are quite different in structure, for their internal cores contain a regular arrangement of rod-like proteins that are responsible for a rhythmic beating of the cilia. Waves of ciliary movement help to clear the surface of adherent mucus and dust particles. The tail of a spermatozoon is like an extremely long cilium with the internal structure discussed above.

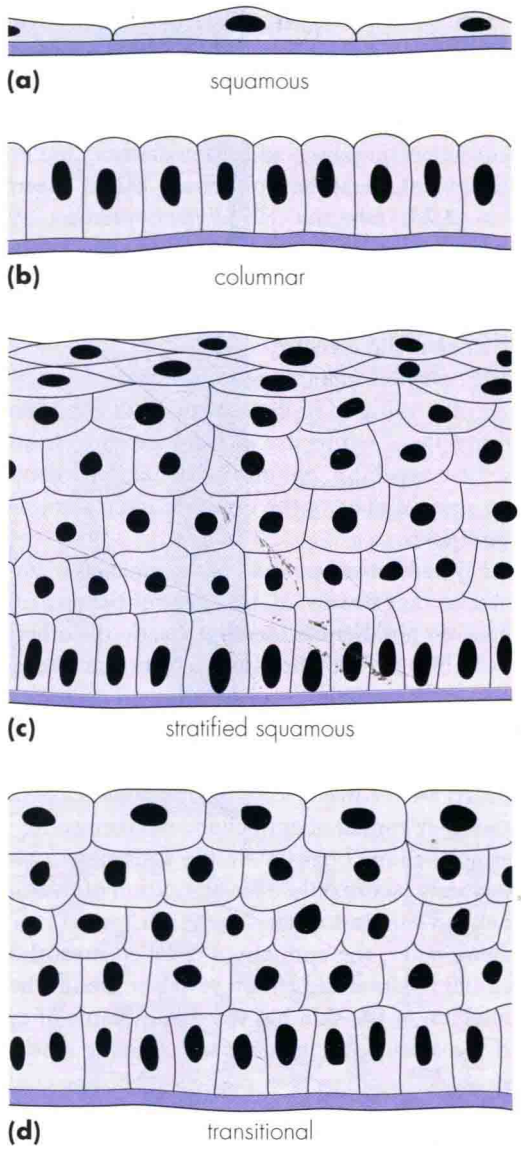
Minute **filaments** and **microtubules** in the cytoplasm act as a kind of internal scaffolding for cells, helping them to preserve their usual shape. Tubules, as in certain nerve cells, may act as transport channels to conduct materials from one region of the cell to another. In muscle cells, the filaments (myofilaments) are composed of special proteins which can 'latch on' to one another to cause contraction.

TISSUES

There are four basic **tissues**: epithelium (epithelial tissue), connective tissue, muscle (muscular tissue) and nerve (nervous tissue). Every structure in the body is made up of varying combinations of these tissues.

EPITHELIUM

Epithelial tissues form sheets of cells that cover surfaces, line cavities, and form glands. As a covering tissue, epithelium forms the outer part of the skin and the thin layer of cells on the outer surface of many organs in the thorax and abdomen (e.g. the lungs, stomach and intestine). As an internal lining, it is found as the innermost layer of cells in hollow viscera



2.2

Fig. 2.2 Examples of simple and stratified epithelia.
(a) Squamous
(b) Columnar
(c) Stratified squamous
(d) Transitional

(such as the stomach), and as the main component of organs made up of tubular structures, such as the kidney and testis.

Epithelial tissues are classified as **simple epithelia** if they consist of a single layer of cells, or **stratified epithelia** if they consist of several layers. Among the simple epithelia are the extremely flattened, *squamous* cells (**2.2a**) ('squamous' meaning 'leaf-like') that form the lining of the alveoli (the air sacs) of the lungs (p.75), and the taller (*columnar*) cells (**2.2b**) that line the intestines (p.81). Organs such as the mouth (p.147),

the oesophagus (p.103) and the vagina (p.301) are lined by thicker epithelia called **stratified squamous epithelia** (**2.2c**) – 'stratified' because there are several layers, and 'squamous' because the uppermost layers of cells are flattened. The parts of the kidneys that collect urine, as well as the rest of the urinary tract (ureters, urinary bladder and urethra), are lined by a special kind of stratified epithelium called *transitional* epithelium (**2.2d**); here the cells of the uppermost layer are not flattened but remain rather bulbous, to allow for stretching when the organ becomes distended (p.293), a feature of particular importance in the bladder which is subject to frequent distension and collapse.

The term **mucous membrane** (or **mucosa**) is used to refer to the internal lining of hollow organs that communicate, whether directly or indirectly, with the exterior. It includes not only the epithelium, but also some underlying connective tissue, and, in most of the digestive tract, some smooth muscle too (p.81).

Despite the adjective 'mucous', not all mucous membranes secrete mucus; they usually do, but those of the urinary tract, for example, do not. **Serous membranes**, on the other hand, line body cavities that do not communicate with the exterior (such as the thoracic cavity), and are reflected over the organs in those cavities. The pleura (in the thorax), the peritoneum (in the abdomen and pelvis) and the pericardium (surrounding the heart) are the major serous membranes. Like mucous membranes they consist of epithelium and connective tissue, with the epithelium being a simple squamous type that secretes a watery (**serous**) fluid for lubrication of the surfaces.

Epithelia in certain localities are given special names: in serous membranes, the epithelium is called **mesothelium**, and when lining blood and lymph vessels it is **endothelium**. The epithelium of the skin has the special name of **epidermis**, and is a stratified squamous keratinizing epithelium, where the uppermost layers of cells have become converted into keratin (p.17).

CONNECTIVE TISSUE

Connective tissue is a supporting tissue that helps to bind other tissues together. Unlike epithelial tissue, which consists almost entirely of cells, connective tissue contains not only cells but a considerable amount of material around and between the cells – the **extracellular matrix** (ECM). The matrix consists of **fibres** and a 'ground' substance containing a variety of macromolecules. Both of these components of the matrix are manufactured by the principal kind of connective tissue cell – the **fibroblasts**. Other common connective tissue cells are the **macrophages**, the 'scavengers' of the body, which help to get rid of unwanted material (such as dead and dying cells and invading organisms). The fibres of connective tissue may be *collagenous* or *elastic*; collagenous fibres are tough and unyielding, while elastic fibres are thin and stretchable. Both are widely distributed throughout the body, but sometimes collagen fibres are aggregated together to form such structures as ligaments and tendons.

There are several different types of connective tissue, ranging from **areolar tissue**, which is loose, such as is found under some areas of the skin, allowing a fold to be pinched up (as on the back of the hand), to **dense connective tissue**, as in tendons, where there are many fibres and very little ground substance. In **adipose tissue**, which is fatty, many of the cells contain large globules of lipid in their cytoplasm. In **cartilage** and **bone** the matrix contains many fibres and is firm (in cartilage) and impregnated with calcium salts (in bone). At the other extreme is **blood**, which is a connective tissue where the matrix is fluid (i.e. **blood plasma**) with red and white blood cells suspended in it and with no fibres – however, when it clots, even blood has fibres.

Bone

If a **bone** is sawn open (**2.3**), it can be seen to consist of an outer shell of **compact bone**, which appears as a dense mass, as in the shaft of a long limb bone, and **cancellous** or **spongy bone**, which partly or completely fills the inside of the bone and consists of a network of fine bone **spicules** (also called **trabeculae**, from the Latin meaning little beams). The bone trabeculae are not randomly arranged, but develop in such a way as to resist the stress to which the bone is usually subjected.

Microscopically (**2.3d**), both types of bone consist of masses of bone cells, the **osteocytes**, and **collagen fibres** embedded in the **calcified matrix**. Despite the solid appearance of much of it, bone is a very vascular tissue and bleeds when cut; in compact bone, for example, there are many capillary blood vessels (with lymphatics and nerve fibres) running in minute tunnels through the matrix (the **Haversian** and **Volkmann's canals**). Many of the osteocytes lie in concentric rings (*lamellae*) of matrix arranged around a capillary; the combination of vessel, cells and matrix (with its embedded collagen fibres) forms a **Haversian system**. The spaces, or *lacunae*, in the matrix in which the bone cells lie are connected to adjacent lacunae by minute channels – called **canaliculi** – so that tissue fluid from nearby capillaries can diffuse through the canaliculi and so reach every bone cell.

All internal bone surfaces are lined by a single layer of cells that is called the **endosteum**. Unless covered by cartilage at the joints, the outer surfaces of bones are ensheathed in **periosteum**, which is a kind of fibrous tissue 'stocking' consisting of several layers of cells, the deepest of which are osteoblasts. **Osteoblasts** form the **osteogenic** layer and lie against the bone surface; they are capable of multiplying and forming new bone, as at a fracture site or at the surface of a bone during development; osteocytes, in contrast, are not capable of cell division. Periosteum is vascular, and also has a good nerve supply; any bruised bone, where the periosteum becomes raised from the surface and stretched by escaped blood, is very painful.