A guide to important principles

Essential Anatomy

SECOND EDITION

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THIS SERIES REPRESENTS A NEW APPROACH to medical education. Each title has been written by a leading expert who is in close touch with the education in his particular field.

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Preface

Anatomy to most people is a subject which suggests the cutting up of dead bodies (the word literally means *cutting up*). In addition it is generally known that Vesalius published a book in 1543 in which much of the human body was described in detail and more or less accurately. A subject which is dead and ancient frequently has little appeal especially if it appears to involve learning a large amount of factual information. For many years anatomy has had to struggle with these disadvantages and at times one has had the impression that there is almost a conspiracy on the part of everyone to suggest that anatomy is unnecessary. There is no doubt, however that a knowledge of the structures of the body, for that is what anatomy is, whether it is what can be seen with the naked eye or with different kinds of microscope, is an essential preliminary and corollary to the understanding of the functions of the body. It was no historical accident that Vesalius, the anatomist, preceded Harvey, the physiologist. No apology need be made for trying to present the basic facts of anatomy to anyone interested in the human body and to members of any profession which will have to cope with the physical and mental problems of children, men and women in health and in sickness. It is not intended that the reader should know everything contained in this book. It is hoped, however, that with the help and guidance of teachers, a comprehension of the structure and function of the human body will be acquired more easily if more information is available than the bare minimum. On the whole, the criterion used for including any information is whether it is likely to help the understanding of how the human body works, and also to stimulate interest for further study.

My thanks are due to Miss Mary Waldron and Mrs. Carol Dawbarn for the drawings and Mr. D. G. T. Bloomer of MTP Press Limited for his cooperation in producing the book.

Introduction

The scheme of this book will not differ very much from that of many other textbooks of anatomy with perhaps one important difference. There will be a special emphasis on the functions of what is described. Inevitably one must begin with the *cell*, which is regarded as the basic unit of any living, complex organism. Cells form *tissues* which are aggregated to form *organs*. The cells of different organs vary in their structure and organization, and associated with this variation are the different functions they perform. Complexity of the organism has also resulted in different parts having different functions and where one group of structures has similar functions one refers to a *system* of the body, for example, the heart and blood vessels constitute the *cardiovascular* or *circulatory system*.

Terminology in human anatomy

Certain terms are used for descriptive purposes in human anatomy. The *anatomical position* is one in which the body is upright with the palms of the hands facing forwards and the feet pointing forwards. *Medial* means nearer to and *lateral* means further from the midline, that is the thumb and little toe in the anatomical position are lateral and the little finger and big toe are medial. The front is *anterior* (*ventral*) and the back is *posterior* (*dorsal*). There are three planes, *sagittal*—a vertical plane anteroposteriorly, *coronal* (*frontal*)—a vertical plane from side to side, and *transverse*—a horizontal plane (Fig. 1). *Superior* (*cranial*) means nearer the head and *inferior* (*caudal*) nearer the feet. In the limbs *proximal* and *distal* are often used as synonyms for superior and inferior. *Superficial* means nearer the surface of the body as opposed to *deep* meaning further from the surface.

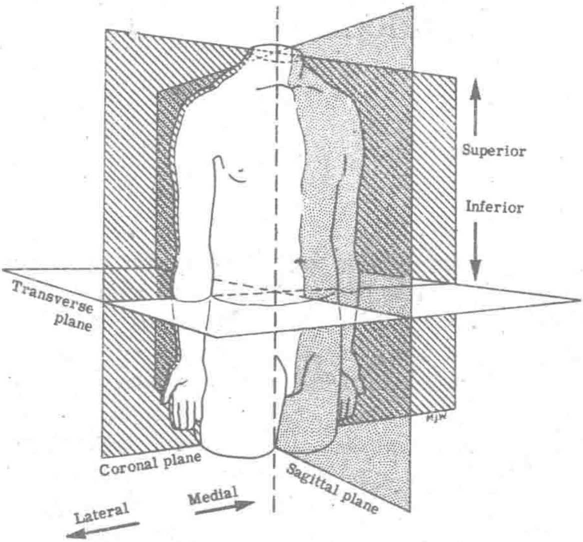

Fig.1. Terminology in human anatomy.

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1

Cells

It is not easy to distinguish between living and non-living matter. If one has to make a distinction perhaps living matter may be said to have the capacity to use energy, excrete, reproduce itself and pass on to what it has reproduced its own characteristics (heredity). If this definition is accepted the lowest form of living matter is probably a *bacterium*. A virus can be regarded as an intermediate form between living and non-living.

The cell

The unit of living matter is called a *cell* (Fig.2). For practical purposes all cells consist of *cytoplasm* containing a *nucleus*. The nucleus consists largely of *water*, and *nucleic acid* and *proteins* in combination. The cytoplasm consists largely of water containing proteins which are found in many of the structures referred to below, for example, mitochondria, ribosomes. The cell is surrounded by a *cell membrane* and the nucleus by a *nuclear membrane*, both containing protein and lipid. Viruses consist almost entirely of nuclear material containing *nucleoproteins* and are able to use the proteins manufactured for them by the cell. For this purpose a virus has to use the *enzymes* of the cell (enzymes are similar to *catalysts*—they hasten a chemical change without taking part in the chemical change itself). Viruses therefore live inside other cells. They may destroy these cells or they may live in harmony with them. The former occurs in many diseases; for example, poliomyelitis (infantile paralysis) is due to a virus infection of certain nerve cells in the spinal cord and possibly the brain. Bacteria, bigger than viruses, have their own enzyme systems and can therefore exist independently of other cells.

The nucleus of a cell contains *deoxyribonucleic acid* (DNA) which

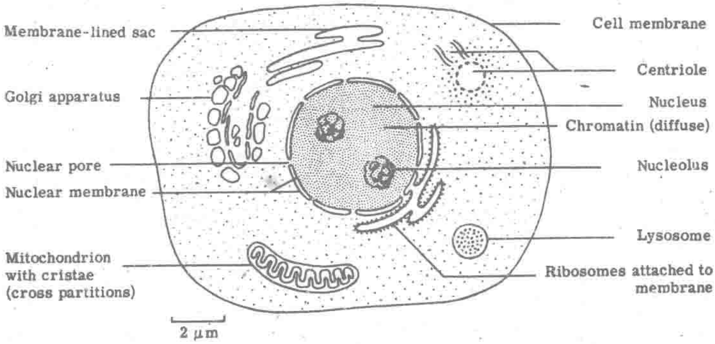

Fig.2. The cell and its organelles.

is responsible for the production of *ribonucleic acid* (RNA). Within the nucleus is the *nucleolus* (there may be more than one) which is rich in RNA. These nucleoli are the centres of ribosome synthesis. The DNA of the nucleus is localized in the *chromatin* of the nucleus. This chromatin is not easily seen unless the cell is preparing to divide, when the *chromosomes* which contain the hereditary characteristics of the cell become visible. The DNA determines the pattern of the proteins to be formed and the RNA is actually responsible for their formation. It passes from the nucleus through pores in the nuclear membrane into the cytoplasm of the cell. Here the nuclear RNA becomes attached to the cytoplasmic *ribosomes* where specific proteins are formed from more elementary compounds called *amino acids*, the source of which is digested food. These enzymes are found in relation to the ribosomes. Enzymes are also found in the *mitochondria* of the cytoplasm, and function in the building up of energy-rich compounds. These energy-rich compounds are used in all activities of the cell. During this process oxygen is usually required and waste is produced in the form of water and carbon dioxide. The role of proteins in the structure and function of the cell can now be appreciated. *Lysosomes* contain enzymes which break down substances and would have this effect on the cell itself were they not contained in a membrane.

There are other structures in the cytoplasm such as the *centriole* which is involved in the division of the cell and the *Golgi apparatus* which is important in the formation of a cell's secretion. The cell membrane is so constructed that it can determine what passes into and out of the cell. This is called a *selective membrane*.

Both plants and animals consist of cells but the main distinguishing feature is that plants possess a green pigment, *chlorophyll*, which is used in a process called *photosynthesis*. By this process, which utilizes solar energy, the plant makes its own food from water and carbon dioxide. There are some unicellular organisms which use both photosynthesis and digestion of complex substances as means of obtaining food.

Certain terms are used in order to measure very small structures such as viruses, bacteria and cells. A μm (μ is the Greek letter 'm') is 1/1,000 of a millimetre and an nm is 1/1,000,000 of a millimetre, or 1/1,000 of a μm. A virus is about 50 nm in diameter, a bacterium is about 1 μm in diameter and an average cell is about 15 μm in diameter. Obviously there are large and small cells, etc. Most viruses and some of the structures in the cell referred to above can be seen only with an electron microscope which can magnify 1,000 to 200,000 times. Bacteria and cells can be seen with a light microscope which can magnify up to 1,000 times.

Single-cell organisms

It is useful to know something about the properties of a living cell. This may be best studied in a single-cell organism such as the *amoeba*.

a. Growth: an amoeba can increase in size up to a point. This is due to its being able to undergo .

b. Metabolism: this process involves (1) the ingestion, (2) the digestion, (3) the assimilation of food. Metabolism occurs not only in growth but in almost every function of the cell, including repair. The process of metabolism involves the use of energy, the participation of enzymes and the elimination of waste products. In other words, if an amoeba were unable to ingest the right food, break it down by utilizing a source of energy with the help of enzymes, build up the broken-down products to form the substances it requires and get rid of any waste products produced in these processes, then the amoeba would die. The utilization of oxygen and production of carbon dioxide is usually called *respiration*.

c. Reproduction: the amoeba reproduces by dividing into two daughter cells. In this process the nucleus divides into two in such a way that the daughter cells are the same as the mother cell except for size.

d. *Motility*: amoebae move by pushing out some of their cytoplasm and retracting another part, that is, by the formation of *pseudopodia*.

e. *Reacting to the environment*: this includes the movements involved in engulfing a particle of food as well as reactions such as movement away from an obstacle.

Many of the functions of the cell are directed towards maintaining its equilibrium in a variable environment, that is, the cell exhibits *homeostasis* but there is obviously a limit to the changes to which the cell can react without damage or destruction.

Unicellular organisms are classified as *protozoa*. It is interesting to consider another type of unicellular organism in which different parts of the same cell have become specialized for certain functions, the *paramecium*. Unlike the amoeba, this organism has a permanent shape with a front and back end. Food is ingested at only one place and not anywhere on the surface. Movement is by means of *cilia*—hairlike structures projecting from the surface and beating rhythmically. Reproduction is preceded by an exchange of nuclear material between two paramecia followed by division. Respiration and excretion, however, takes place over the whole surface.

Multiple-cell organisms

In multicellular organisms *specialization* takes place so that groups of cells have a different structure and function. Cells are specialized for reproduction, movement, digestion, excretion and receiving information (both from the environment and the body itself). In addition, a single function may require a complex arrangement; for example, the conveying of oxygen to the tissues requires a pump and an involved system of tubes. There are many ways of subdividing the millions and millions of cells which constitute any animal. They may be subdivided into *tissues* because they have a common origin or function or position. Cells also constitute *organs* which are usually mixtures or different tissues or they may form *systems* because the various parts serve a fairly common function.

2

Tissues

Classification of tissues presents a problem because it is often difficult to find a basis which rigidly confines certain structures to one group. Traditionally tissues are said to be:

a. Epithelial when on a surface either outside or inside the body,

b. Connective when they form packing and supporting tissue,

c. Muscular if they are contractile,

d. Nervous if they possess conductivity.

This classification appears to depend on site or function. It leaves out fluid such as *blood* and *lymph*. It disregards embryological origin (for example, epithelia are ectodermal, mesodermal or endodermal in origin, all connective tissue is mesodermal and almost all nervous tissue is ectodermal). It also appears to exclude certain specialized tissues, for example, glandular and lymphoid tissue. The former is derived from epithelial tissue as a rule and the latter may be included among connective tissue.

Epithelial tissue

This tissue covers a surface which may be external (as in the skin) or internal (in the mouth or alimentary tract) or lining a vessel (blood or lymphatic). Epithelial tissue is said to be *simple* or *compound* (Table 1).

SIMPLE. This type consists of a single layer of cells whose shape gives the epithelium its name.

a. Squamous (*pavement*) (Fig.3a) has flattened cells and is found lining blood vessels and the chamber of the heart (it is usually called *endothelium* in these structures).

Table I

- EPITHELIA
  - SIMPLE
    - SQUAMOUS
    - CUBOIDAL
    - COLUMNAR
      - ORDINARY
      - MUCOUS
      - CILIATED
  - COMPOUND
    - TRANSITIONAL
    - STRATIFIED SQUAMOUS

b. Cuboidal (Fig.3b) has roughly cube-shaped cells and is found lining the ducts of some glands and the acini of the thyroid gland.

c. Columnar (Fig.3c) consists of taller cells and is found lining the stomach and intestines. This type frequently includes cells (*goblet cells*) which produce *mucus* (Fig.3d) and the epithelium is then called *mucous columnar*. If the cells have hair-like processes (cilia) projecting from their free surface it is called *ciliated columnar epithelium* (Fig.3e).

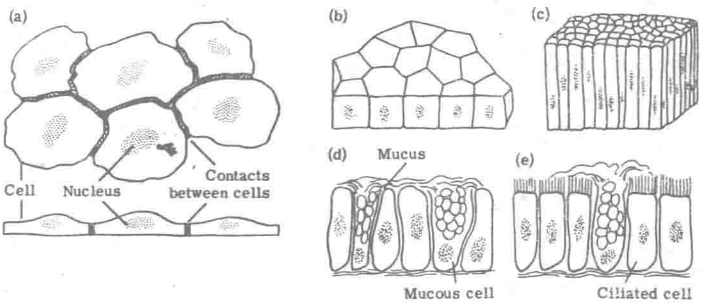

Fig.3. Simple epithelia: (a) Squamous, (b) Cuboidal, (c) Ordinary columnar, (d) Mucous columnar, (e) Ciliated mucous columnar.

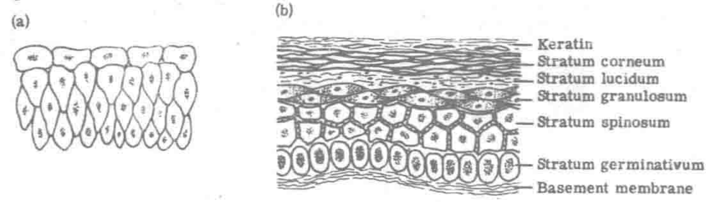

Fig.4. Compound (stratified) epithelia: (a) Transitional, (b) Keratinized stratified squamous.

COMPOUND. In this type of epithelium there are several layers of cells. There are two varieties of compound (*stratified*) epithelium.

a. Transitional (Fig.4a), found only in the urinary passages, mainly the ureter and bladder, consists of about three to five layers of cells which are frequently pear-shaped. When the bladder is distended the epithelial lining is very much thinner than when the bladder is small. This change in thickness is one of the characteristics of transitional epithelium.

b. Stratified squamous is called this somewhat confusing name because there are several layers, the most superficial of which are flattened (Fig.4b) The deepest layer of this epithelium is the source of the cells of all the other layers and it consists of large columnar cells. The middle layers are more polyhedral and the most superficial layer is flattened. This type of epithelium is found in the mouth and oesophagus. This epithelium is also found in the superficial part of the skin and in this position the most superficial layer consists of a layer of flattened dead cells containing *keratin*. Hence the terms *keratinized* and *non-keratinized* stratified squamous epithelium. Keratin is a hard, horny-like substance and has a protective function. The formation of the keratin can be traced through the successive layer of cells as changes in the granules in the cytoplasm of the cells forming these layers.

The keratinized stratified squamous epithelium of the skin is called the *epidermis*. The deeper layer of the skin is called the *dermis* and consists of connective tissue. *Nails*, *hairs* with their associated *sebaceous glands* and *sweat glands* are all modifications of the cells of the epidermis (Fig.5). The hairs and sweat glands are down-growths of epidermal cells into the underlying dermis and the sebaceous glands develop from the cells which form the hair. Stratified squamous epithelium is often called the *wear and tear* epithelium because it is found where the surface cells are easily removed by injury or rubbing.

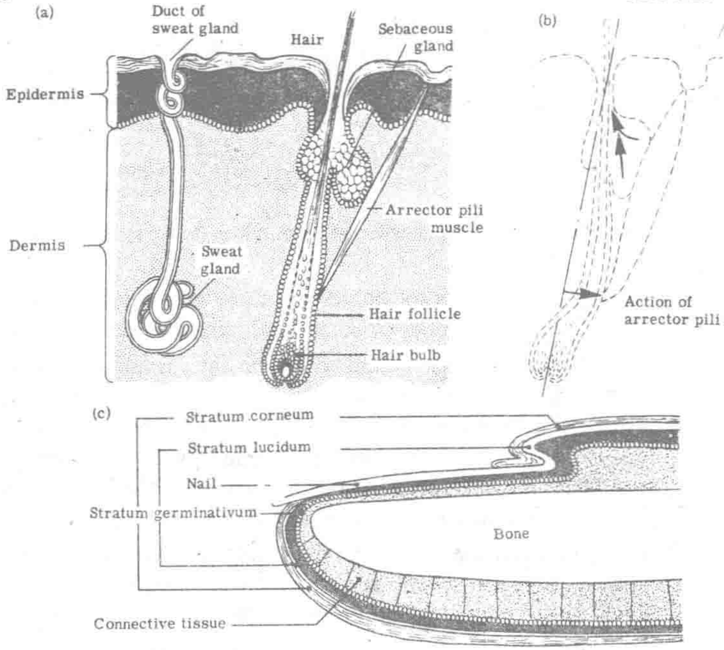

Fig.5. (a) Derivatives of epidermis (sweat gland, hair follicle and hair, sebaceous gland), (b) Action of arrector pili muscle (straightening of hair, pulling down of skin as in goose pimples, possibly squeeze sebaceous gland), (c) Longitudinal section through terminal part of finger to show relation of nail to epidermis.

Glandular tissue

Because these structures usually develop from and are often related to epithelial tissues they are dealt with at this stage. Glands which open on to the surface either directly or through a duct are called *exocrine* as opposed to the *ductless* (*endocrine*) *glands* whose secretion passes directly into the blood stream. The goblet cells of a mucous columnar epithelium may be regarded as a single-celled gland. If, as in the stomach, the cells grow down into the underlying tissue a *simple tubular gland* (Fig.6a) is formed. In another type of gland the down-growing tube branches at its end and subsequently only the branches become secretory. This is called an *alveolar gland* (Fig.6b). In some glands secretory cells are arranged round the duct in a spherical or tubular manner. Sometimes the ducts branch before the secretory tissue is formed and if the secretory tissue is racemose in its arrangement the gland is called a *compound racemose* or *alveolar gland* (racemose = like a bunch of grapes) (Fig.6c).

Glands are normally named after the type of secretion they pro-

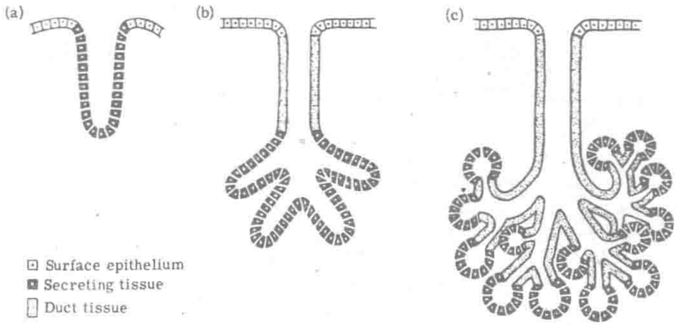

Fig.6. (a) Simple tubular gland, (b) Alveolar gland, (c) Compound alveolar gland.

duce, for example, *salivary glands*, *sweat glands*, *sebaceous glands*. The cells of glandular tissue may produce their secretion without much change in the basic structure of the cell (*merocrine glands*). This is commonly found throughout the body. On the other hand the luminal part of the cell may break off altogether with the accumulated secretion (*apocrine glands*). This is found in the sweat glands of the arm-pit. Sometimes the whole cell disintegrates (*holocrine glands*). This is found in the sebaceous glands of the skin.

During the production of secretion the mitochondria of the cell are very active and the nucleus undergoes changes both in position (it moves towards the base of the cell and away from the luminal edge) and structure. The secretory granules or globules accumulate near the luminal side of the cell before being released in one of the ways described above.

Connective tissue

Basically connective tissue consists of *cells* embedded in a *ground substance* containing *fibres* (Fig.7a). The state of the ground substance and its composition, and the type and quantity of the fibres determine which type of connective tissue one is dealing with. The cells are all derived from one basic type of cell called a *mesenchyme cell* Subsequently many types of cell are found and these are named according to their main function. A variety of cells and fibres, however, may be found in certain types of connective tissue which will be classified later on.

CELLS. A *fibrocyte* (Fig.7a) is the basic cell found in *fibrous tissue*.