# Basic Physiology

Edited by
**P.D. Sturkie**

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# Preface

**Basic Physiology** is an introduction to vertebrate physiology, stressing human physiology at the organ level, and including requisite anatomy integrated with function. One chapter deals solely with topographic anatomy in atlas form and microscopic anatomy of the principal tissues of the body. Additional chapters cover cellular and general physiology; nervous system, muscle; blood and tissue fluids, heart and circulation; respiration, digestion and absorption; intermediary metabolism; energy metabolism; temperature regulation; nutrition; kidney; endocrinology, including hypophysis, reproduction; thyroids, parathyroids, adrenals and pancreas. All concepts are emphasized and well illustrated, and controversial material is omitted. It is written at a level suited to undergraduate students who have had introductory courses in biology, chemistry, and mathematics, and to more advanced students who wish to review the basic concepts of physiology.

This volume should be especially useful as a text for departments of biology, zoology, nursing, health, and agricultural sciences that offer courses in vertebrate and human physiology.

**Basic Physiology** is written by seven subject matter specialists who have considerable experience in teaching their specialty to undergraduates studying physiology and biology.

Paul D. Sturkie

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# Chapter 1

# Tissues, Organs, and Skeletal Organization



The body is made up of systems that comprise organs, tissues, and cells. These systems, which carry out all of the body's functions include the: 1) skeletal, 2) muscular, 3) nervous, 4) circulatory, 5) digestive, 6) respiratory, 7) urogenital (including reproductive and excretory systems), and 8) endocrine.

The unit of structure and function of systems, organs, and tissues is the cell, discussed in Chapter 2.

*Anatomy* is the study of the structure of an organ or system, both gross and microscopic. Gross or systematic anatomy is concerned with the appearance and characteristics of a system or organ as seen with the naked eye. Microscopic anatomy (histology and cytology) deals with structure at the level of tissues and cells, respectively.

This chapter will deal briefly with the histology of the principal tissues and organs systems of the body, and with gross and topographic anatomy. Further anatomic details will be considered and integrated with the physiology under the appropriate chapters and headings.

## Terminology

The terms used to describe location and position of bodily parts are listed in Table 1.1 and Fig. 1.1

Planes or sections of the body and tisues are depicted in Fig. 1.2 and include: 1) sagittal, medial, or longitudinal; 2) transverse, cross, or horizontal; and 3) frontal or coronal.

The most commonly used histologic specimens are those that are cut in cross and longitudinal sections.

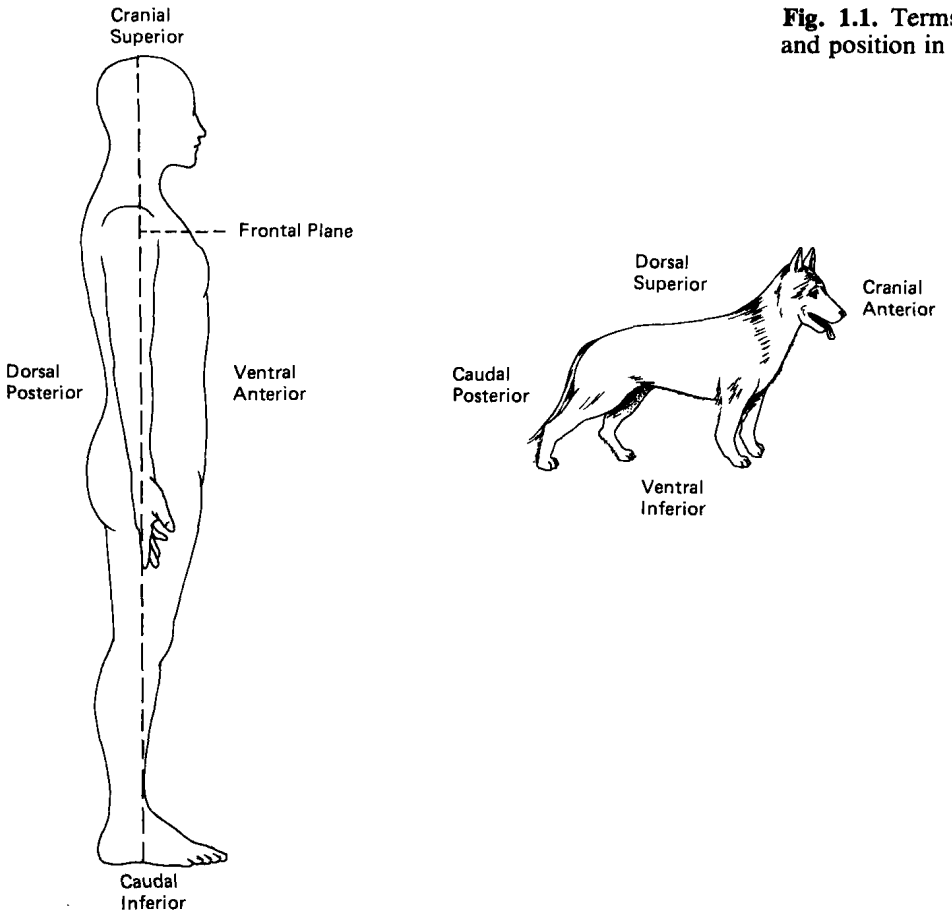



**Fig. 1.1.** Terms designating location and position in man and quadruped.

**Table 1.1.** Terms of location and position of body parts in man and quadruped

| Man | Quadruped |
|---|---|
| Superior or cranial | *Anterior* or cranial |
| *Anterior* or ventral | Inferior or *ventral* |
| *Posterior* or dorsal | Superior or *dorsal* |

Medial—near middle or median; nose is medial to eyes
Lateral—to the side (farther); eyes are lateral to nose
Proximal—nearest to; proximal joint of toe is nearest to foot
Distal—farther from; toenail is distal to foot
Peripheral—extension from central; spinal nerves are peripheral to the brain
Visceral—organs within a cavity; intestinal organs

* The commoner term is shown in italics.

# Tissues

Organs and systems of the body are composed of one or more tissues with characteristic structures. They include: 1) epithelium, 2) skin, 3) membranes, 4) muscle, 5) nerve, 6)

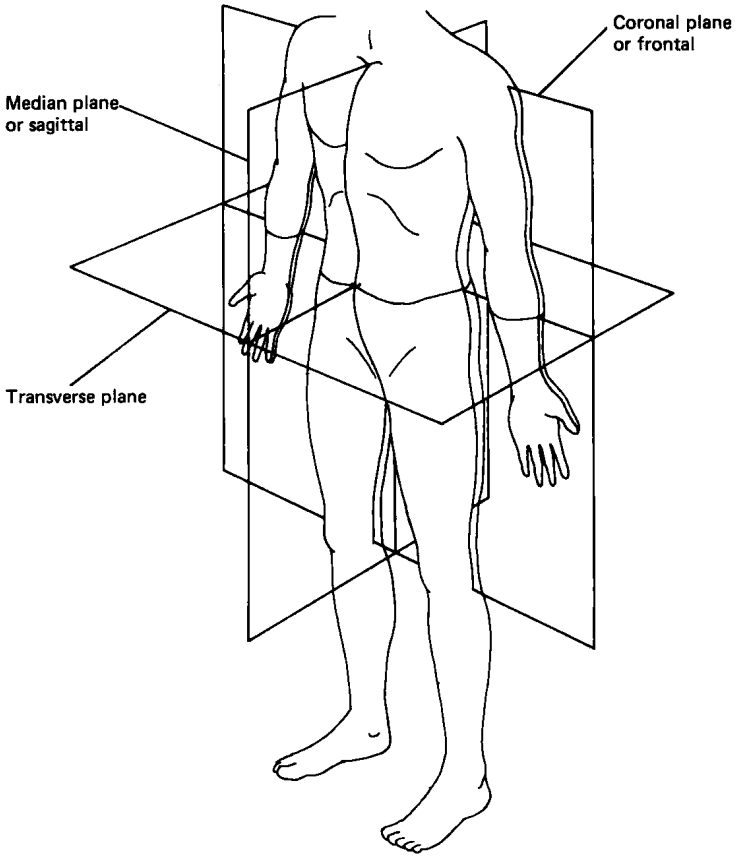
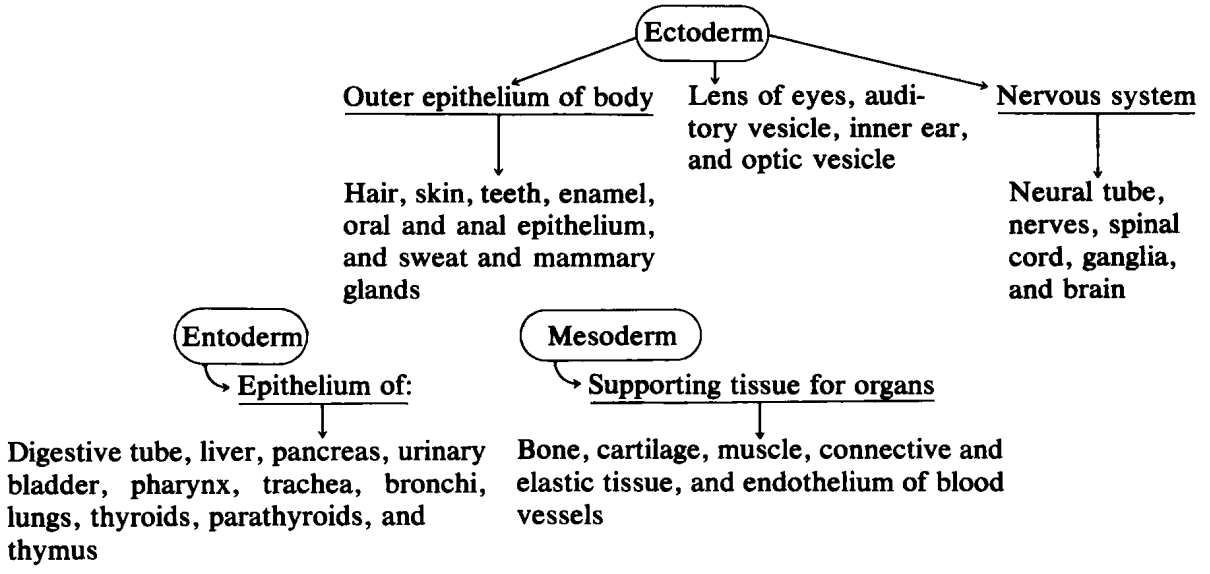



**Fig. 1.2.** The planes of the body.

connective tissue, 7) elastic tissue, 8) cartilage, and 9) bone. These tissues are derived embryologically from three germ layers, including: 1) ectoderm, 2) entoderm, and 3) mesoderm. Certain organs and tissues are derived from these germ layers as shown in Fig. 1.3.

**Fig. 1.3.** Derivatives of the three embryonic germ layers.



## Epithelial Tissues

Epithelial tissues are composed of adhering cells, arranged to form a covering membrane over the external surfaces and internal (lining) surfaces of the body. There are no blood vessels in these cells. Types and location of these cells include:

*Simple squamous:* One layer of flat cells found lining alveoli of lungs, lens of eye, and part of inner ear.

*Stratified squamous:* Flat and many layered cells found ir epidermis of skin (Fig. 1.4A). As skin thickens, flat squa mous cells are rubbed off and new cells are formed from lower layers (stratum germinativum).

*Endothelial:* One layer of cells lining interior surface of blood and lymph vessels.

*Columnar:* Cells are tall and cylindrical; nucleus is located near base of cell; cytoplasm contains numerous mitochondria and golgi apparatus (Fig. 1.4C); found in the lining of stomach and intestines; the cells may be plain or have cilia (hairlike motile projections); there may also be microvilli, small folds in the vascular projections of intestines that increase the absorption surface.

*Cuboidal:* Similar to columnar cells, but cuboidal and found in the liver.

## Glands and Membranes

*Exocrine glands* have secretions which drain into a duct and are then carried to the bloodstream in contrast to a *ductless gland* (see Chap. 25). They have different shapes and numbers of ducts and are lined with columnar, cuboidal, or flat-squamous epithelium. The glands are classified according both to type and shape and to whether they are branched or unbranched (simple); their ducts may also be branched or unbranched (Fig. 1.5).

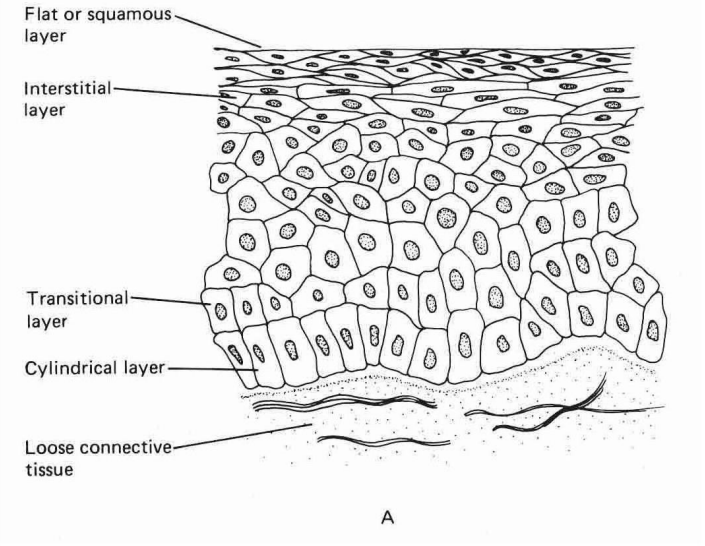
Epithelium and the underlying tissues form a membrane, a structure covering or enveloping another tissue (see Chap. 2). These membranes line the body cavities and organs therein and may secrete a thin serous fluid or a thick mucous one.

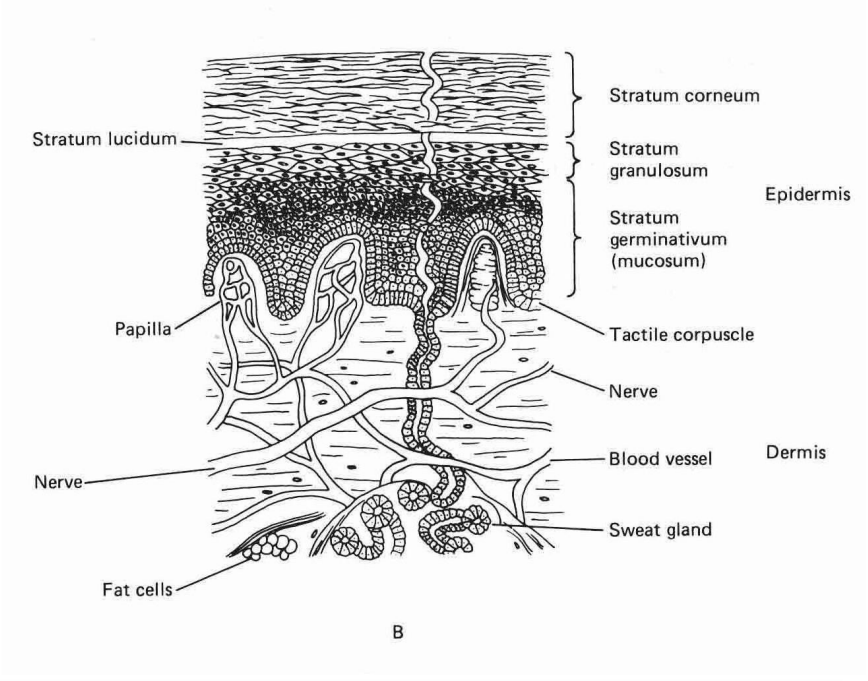
The lining of blood vessels is an endothelial membrane made up of endothelial cells and connective tissue. Other membranes include: *pericardium* (surrounding the heart), *peritoneum* (lining the abdominal cavity), and *pleura* (two in number, covering the lungs and chest cavity).

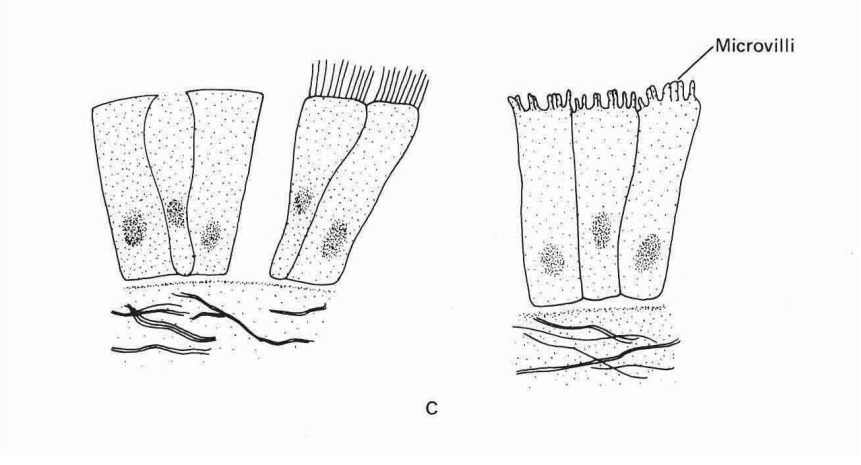
*Synovial membranes* are associated with bones and muscles and consist of a tough outer layer of fibrous tissue and an inner layer of areolar connective tissue containing elastic and collagenous fibers (Fig. 20.2). They secrete synovial fluid (tissue fluid and mucin), which serves as a lubricant to protect knee and elbow joints and to reduce friction therein.

*Mucous membranes* secrete mucus and line the alimentary

**Fig. 1.4.A–C.** Cellular morphology. **A** Flat or squamous epithelium. **B** Same type of epithelium in skin, showing three layers of epidermis and dermis, with nerve cells, tactile corpuscle and sweat glands. **C** Columnar (plain), ciliated, and with microvilli as seen in intestine, and connective tissue.



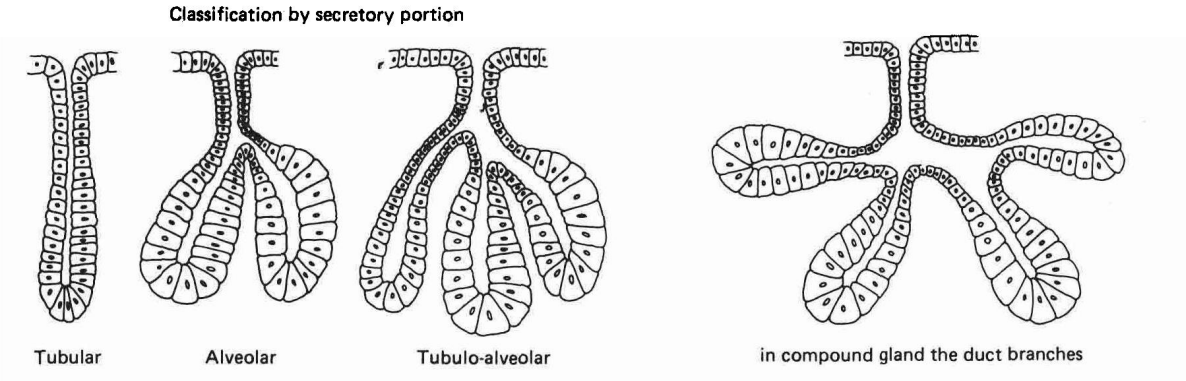



**Fig. 1.5.** Types of glands and branching of glands and ducts.

canal or digestive tube and trachea, bronchi and air sacs of lungs, and many other organs. A mucous membrane is made up of three layers including: 1) epithelium, 2) a supporting lamina propria, 3) a layer of smooth muscle (Fig. 20.2). The function of mucous membranes is 1) to support and protect blood vessels and lymphatics and 2) to provide for large absorptive surfaces such as occur in the intestines.

## Connective Tissues

These tissues support and connect various structures. Although they contain few cells, the intercellular cement or fluid is abundant, and the tissue is highly vascular. The intercellular material and fibers vary and largely determine the type of classification.

### Classification

The classification of connective tissue (CT) is as follows:

**Table 1.2**

- CT
  - Ct proper
    - General
      - Loose-areolar
      - Dense
        - Collagenous
        - Elastic
    - Special
      - Reticular
      - Adipose
      - Pigmented
  - Cartilage
    - Hyaline
    - Fibrous
    - Elastic
  - Bone
    - Compact
    - Spongy

In CT proper the intercellular substance is soft, in cartilage it is firm but flexible, and in bone it is rigid because calcium salts have been deposited in the matrix.

*Areolar* CT is loose, widely distributed and it consists of cells and fibers in a fluid matrix forming a soft and displaceable and translucent tissue (Fig. 1.6A). The fibers are collagenous and elastic, forming a framework for most organs and an envelope or sheath for blood vessels and nerves. The

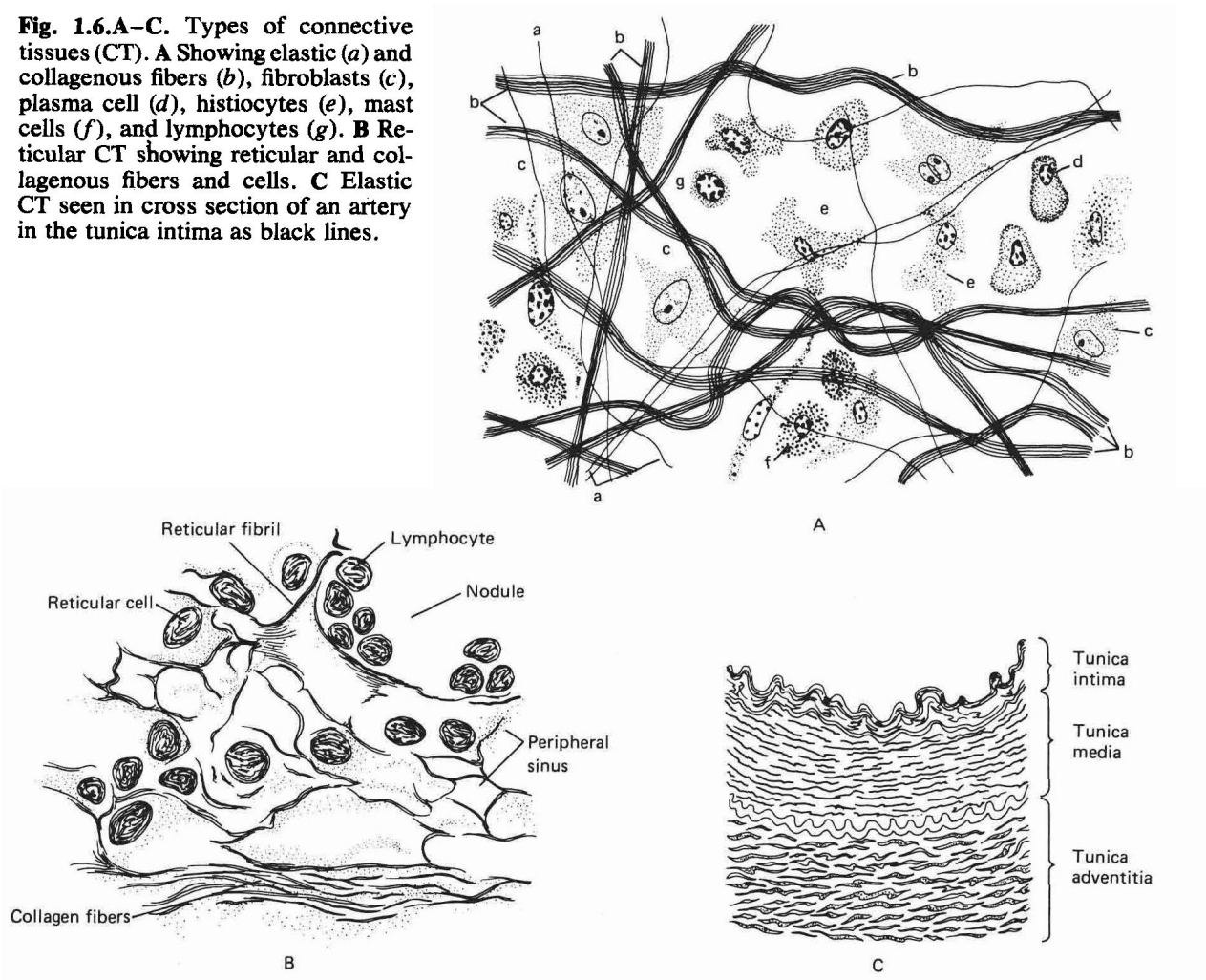



**Fig. 1.6.A–C.** Types of connective tissues (CT). **A** Showing elastic (*a*) and collagenous fibers (*b*), fibroblasts (*c*), plasma cell (*d*), histiocytes (*e*), mast cells (*f*), and lymphocytes (*g*). **B** Reticular CT showing reticular and collagenous fibers and cells. **C** Elastic CT seen in cross section of an artery in the tunica intima as black lines.

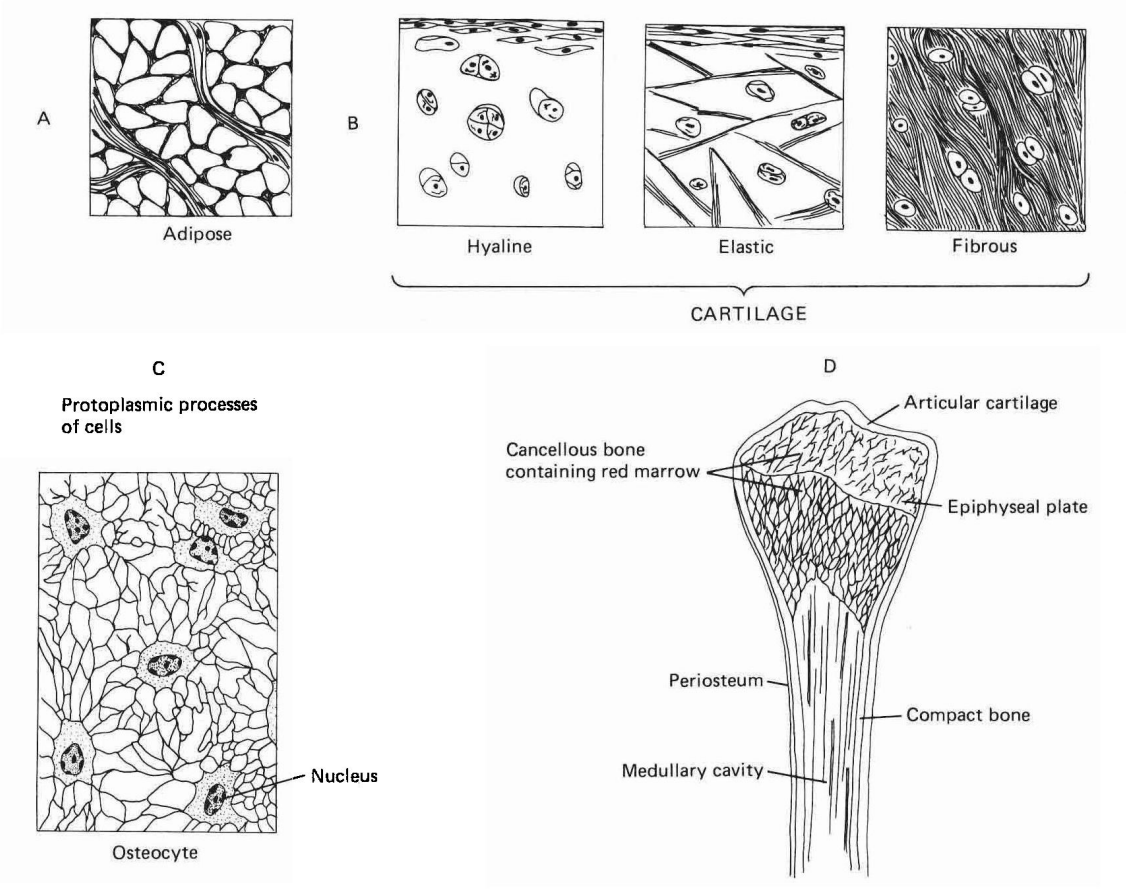
principal cell types are fibroblasts and histiocytes; the latter are phagocytic, i.e., they can physically engulf and digest cells.

*Reticular* CT is characterized by a cellular network (reticulum) of cells and fibrils, both reticular and collagenous (Fig. 1.6B). Reticular tissue forms the framework for lymphatic tissue (lymph nodes), spleen, and bone marrow; the last-mentioned also contains lymphocytes.

*Adipose* CT is characterized by large, ovoid fat cells, and the cytoplasm contains fat droplets. When the fat is dissolved out of the preparation (Fig. 1.7A), the cells appear as empty rings or ovals. Adipose CT is found in subcutaneous fatty deposits throughout the body.

*Elastic* CT is loose CT in which there is a preponderance of elastic fibers. The tissue is distensible and occurs in lung, some cartilage, blood vessels (Fig. 1.6B), bronchial tubes, and elastic ligaments.

*Fibrous* CT is loose CT in which collagenous (fibrous) fibers predominate. Large coarse whitish fibers, they are tough but not distensible. This tissue forms: 1) ligaments, which help to hold bones together at joints, and 2) tendons, which




attach the muscles to bones and which are found in certain membranes that protect organs like heart and kidney.

**Fig. 1.7.A–C.** Adipose tissue, cartilage, and bone. **A** Adipose tissue showing vacuoles (fat cell deposits absorbed) and fibers. **B** Hyaline, elastic, and fibrous cartilage. Cartilage cells in matrix containing elastic fibers and fibrous fibers. **C** Cross section of compact bone, showing cells (osteocytes) in matrix. **D** Longitudinal section of bone showing compact and cancellous (spongy) bone.

## Cartilage

Cartilage is firm but flexible and consists of cells suspended in a variable matrix, or intercellular cement and fibers (Fig. 1.7). *Hyaline* cartilage is a bluish-white, homogenous mass, containing cells and collagenous fibers. It covers the ends of bones at the joints and is found in the ventral ends of ribs of costal cartilage. It is also found in the nose, larynx, trachea, and bronchial tubes.

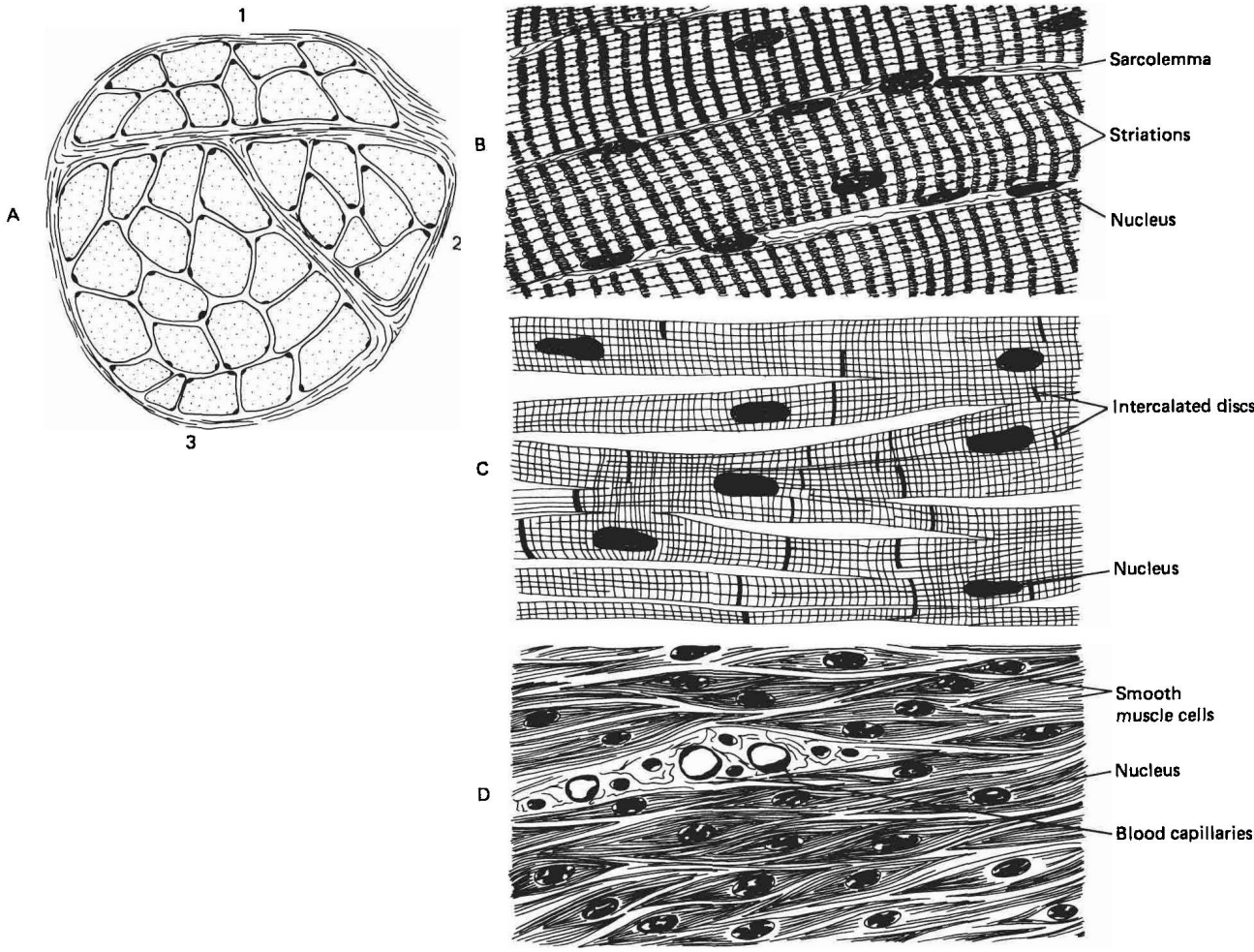
*Elastic* cartilage is CT in which elastic fibers predominate (Fig. 1.7). Found in the larynx, epiglottis, and external ear, it helps to maintain the shape of these organs but permits flexibility. *Fibrous* cartilage contains cells inbedded in fibrous connective tissue. Joining certain bones together, it forms a strong flexible connection where strength and rigidity are required.

## Bone

Bone is connective tissue in which the intercellular substance (matrix) is made hard by salts of calcium and phosphate. This inorganic part comprises about two-thirds the weight of bone. The organic part consists of bone cells (osteocytes and osteoclasts), some cartilage and blood vessels, and nerves (see Chap. 28). Types of bone include: 1) spongy or cancellous (Fig. 1.7), and 2) compact.
The skeleton of an early embryo is preformed in cartilage; later ossification (change of cartilage to bone) begins and continues after birth. In the long bones (Fig. 1.7) the diaphysis (compact bone) is the center of ossification, which proceeds toward the epiphyses, or the ends of bones. Thin layers of cartilage extend between diaphysis and epiphysis. Normal bone is constantly being resorbed by osteoclasts and reformed by osteocytes (see Chap. 28).

## Muscle

Muscle tissue is made up of cells and cellular processes, or fibers. Three types of muscle fibers are delineated, based upon appearance under the light microscope and function. They include: 1) skeletal, 2) cardiac, and 3) smooth or visceral.
Skeletal muscles are under voluntary control by the somatic nervous system, but smooth and cardiac muscle are under involuntary control of the sympathetic nervous system. Skeletal muscles as the name implies are attached to bones of skeleton (see Figs. 1.13 and 1.14); cardiac muscle covers the heart, but smooth muscle forms the muscular portion of visceral organs (digestive organs) and blood vessels.
*Skeletal muscle* is made up of bundles, or fasciculi, containing many muscle fibers (Fig. 1.8A). Each bundle is separated by connective tissue that supplies blood vessels and nerves to the bundles. The individual fibers are cross striated (Fig. 1.8B) and enclosed in a tubular sheath (sarcolemma). Lengths range from 1 to 40 mm, and diameters from 0.01 to 0.15 mm; the fibers are made up of fibrils (myofibrils) that are close packed and which run lengthwise of the muscle fiber. For additional details on structure, see Chap. 11. The color of the striations alternate from light (isotropic, I band) to dark (anisotropic, A band). The combination of an A and I band is called a *sarcomere*. Each band is bisected by a thin dark line called the Z band.
The structure of *cardiac muscle* is similar to that of skeletal in that it is also striated, but unlike the latter there are points at the Z lines where individual fibers abut (merge) or *interdigitate* to form *intercalated discs* (Fig. 1.8C). They produce a strong union between fibers so that contraction in one unit or fiber can be easily transmitted to another unit. Cardiac fibers branch and interdigitate, but each fiber is enclosed by a separate membrane. Cardiac muscle receives




blood from the coronary arteries. See Chaps. 11 & 15 for further details on cardiac muscle.

*Smooth muscle* fibers are not striated (Fig. 1.8D) but are rather long and narrow; each fiber, however, is much shorter than skeletal fibers. Each fiber has only one nucleus, unlike skeletal muscle which has many. Each spindle-shaped cell is about 0.015 to 0.5 mm long and 0.002 to 0.02 mm in diameter. Smooth muscle in the visceral organs and blood vessels is usually arranged in two layers including an inner thick *circular* one, and an outer thin *longitudinal* one. The blood vessels run parallel to the smooth muscle fibers and between the muscle bundles (Fig. 1.8D).

**Fig. 1.8.A–D.** Types of muscle. **A** Cross section showing three (1,2,3) muscle bundles (fasciculi), containing fibers and the connective tissue between the fibers and the bundles. **B** Longitudinal section of skeletal muscle showing individual fibers, sarcolemma, and cross-striations (dark and light bands). **C** Cardiac muscle showing striations and merging of fibers (intercalated discs). **D** Smooth muscle showing individual cells and fibers but no striations.

## Nervous Tissue

Nerve tissue is composed of cells call *neurons;* they differ somewhat in structure and function from other cells. Neurons display the unique functions of 1) irritability, 2) excitability, and 3) conductivity. In other words, neurons receive impulses and conduct or transmit responses to these impulses. Most of the details on the anatomy and histology of