LECTURE NOTES IN HISTOLOGY

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1- Introduction

_ Histology is the study of the tissues of the body and how these tissues are arranged to constitute organs.

_ It was Antony Van Leeuwenhoek (1632_1723), a Dutch draper and scientist, and one of the first man to make and use a real microscope.

_ The cell was first discovered by Robert Hook in 1665. A cell is the structural and functional unit of the body. A group of tissues is incorporated in an organ.

_ There are approximately 37.2 trillion cells in human body. About 300 million cells die every minute in our body and 222-242 billion cells are produced everyday by the average human body.

_ Tissues have two interacting components: cells and extracellular matrix (ECM). The ECM supports the cells and the fluid that transports nutrients to the cells, and carries away their catabolites and secretory products. The cells produce the ECM and are also influenced and sometimes controlled by matrix molecules.

_ The ECM (basement membrane and interstitial matrix) is composed of an interlocking mesh of fibrous proteins and glycosaminoglycans (GAGs). Different types of materials are found within the ECM and these include heparin sulfate, chondroitin sulfate, keratin sulfate, hyaluronic acid and proteins (such as collagen, elastin, fibronectin and laminin).

_ Functions of ECM include cell adhesion, cell-to-cell communication, and differentiation.

_ Animal's cells are eukaryotic and contain membrane-bound organelles, including a nucleus. Eukaryotes can be single-celled or multi-celled. Bacteria are an example of prokaryotes. Prokaryotic cells do not contain a nucleus or any other membrane-bound organelle.

_ The cell is composed of two basic parts: cytoplasm and nucleus. The outermost components of the cell separating the cytoplasm from its extracellular environment, is the plasma membrane (plasmalemma).

_ The cytoplasm consists largely of a fluid component, cytosol, bathing metabolically active structures, the organelles, which may be membranous (such as mitochondria) or non-membranous protein complex (such as ribosomes and proteasomes). In addition to the organelles, there are protein components of the cytoplasmic cytoskeleton, which determines the shape and motility of eukaryotic cells.

_ The plasma membrane (cell membrane) function as a selective barrier regulating the passage of materials into and out of the cell and facilitating the transport of specific molecules. One important role of the cell membrane is to keep constant the ion content of cytoplasm, which differs from that of the extracellular fluid. Membranes also carry out a number of specific recognition and signaling functions, playing a key role in the interactions of the cell with its environment.

_ Ribosomes found in the cytosol are the site of protein synthesis for use within the cytosol (e.g. glycolytic enzymes) or for import into the nucleus and certain other organelles.

_ Principal activities of the rough endoplasmic reticulum (RER) include synthesis and segregation of proteins not destined for the cytosol. Additional functions include the initial (core) glycosylation of glycoproteins, certain other posttranslational modification of newly formed polypeptides and the assembly of multi-chain proteins.

_ The smooth endoplasmic reticulum (SER) synthesizes, transports, and stores lipids (e.g. steroids); metabolizes carbohydrates, detoxifies drugs, alcohol, and poisons; forms vesicles and peroxisomes.

_ The Golgi apparatus modifies, packages, and sorts materials that arrive from the ER in transport vesicles; forms secretory vesicles and lysosomes.

_ The mitochondria synthesize most ATP during aerobic cellular respiration by digestion of fuel molecules (e.g. glucose) in the presence of oxygen.

_ The nucleus is the command center of the cell and it also contains the molecular machinery to replicate the DNA and to synthesize and process all types of RNA.

_ Despite its complexity, the human body is composed of only four basic types of tissues: epithelial, connective, muscular, and nervous.

2- Epithelial Tissue

Q. What is meant by epithelial tissue?

Ans.: Epithelial tissues are composed of closely aggregated polyhedral cells with strong adhesion to one another and attached to a thin layer of ECM. Epithelia are cellular sheets that line the cavities of organs and cover the body surface.

Q. What are the principal functions of epithelial tissues?

Ans.: (1) Covering, lining, and protecting surfaces (e.g. epidermis).

(2) Absorption (e.g. the intestinal lining).

(3) Secretion (e.g. parenchymal cells of glands).

Q. What are the characteristic features of epithelial cells?

Ans.: The shapes and dimensions of epithelial cells are quite variable, ranging from tall columnar to cuboidal to low squamous cells. Epithelial cell nuclei vary in shape and may be elliptic (oval), spherical, or flattened. Nuclear shape corresponds roughly to cell shapes; tall cells have elongated nuclei and squamous cells have flattened nuclei. Cuboidal or pyramidal cells usually have more spherical nuclei. Most epithelia rest on connective tissue that contains the microvasculature bringing nutrients and O_2 to both tissues. Even thick epithelia do not themselves normally contain blood vessels. The connective tissue that underlies the epithelia lining the organs of the digestive, respiratory, and urinary system is called **lamina properia**.

Q. What are the basement membranes?

Ans.: All epithelial cells in contact with adjacent connective tissue have at their basal surfaces a specialized, felt like sheet of extracellular material referred to as the basement membrane. This structure consists of two layers; basal lamina (close to the epithelium) and reticular lamina (beneath the basal lamina).

Q. What are the morphological types of epithelia?

Ans.: (1) An epithelium in which the basement membrane has one cell layer is simple; the cells of different simple epithelia range widely in height, from very thin or squamous, to roughly cuboidal, to very tall or columnar.

(2) Epithelia with two or more layers of cells are stratified and almost all such epithelia are stratified squamous, in which the outer cell layers are thin and flattened.

(3) Cells of stratified squamous epithelia move gradually from the basal to the surface layers, changing shape and becoming filled with keratin intermediate filaments.

(4) Stratified squamous epithelia such as the epidermis cover the body surface, protecting underlying tissues from excess water loss (dehydration) and microbial invasion.

(5) Pseudostratified epithelia are thick and appear to have several cell layers; all cells attach to the basal lamina but not all extend to the free epithelial surface.

(6) Transitional epithelium or urothelium, found only in the lining of the urinary system, is stratified, with large rounded surface cells protective against urine.

Q. What are the functions of the secretory epithelial cells?

Ans.: Secretory epithelial cells may synthesize, store, and release proteins (e.g. in the pancreas), lipid (e.g. adrenal, sebaceous glands), or complexes of carbohydrates and proteins (e.g. salivary glands). Epithelia of mammary glands secrete all three substances. The cells of some glands (e.g. sweat glands) have little synthetic activity and secrete mostly water and electrolytes (ions) transferred from blood.

Q. What are goblet cells?

Ans.: Scattered secretory cells, sometimes called unicellular glands, are common in simple cuboidal, simple columnar, and pseudo-stratified epithelia of many organs. An important, easily seen example is the goblet cell abundant in the lining of the small intestine and respiratory tract, which secretes lubricating mucus that aids the function of these organs.

Q. What are the different types of exocrine glands?

Ans.: A. According to secretion, glands are classified as:

a. Merocrine (also called eccrine secretion) _ common type, secreting protein product by exocytosis.
b. Apocrine _ discharging free, unbroken, membrane-bound vesicles containing secretory products _ lipid products, as in mammary gland and some sweat glands.
c. Holocrine _ discharge of whole secretory cells to release the secretory cells with subsequent disintegration of cells to release the secretory product, e.g. sebaceous glands.

B. According to the morphology of gland:

a. Simple gland _ those with single unbranched duct; secretory portion of the gland may be tubular or acinar (flask _ shaped).
b. Compound gland _ has branched duct system; secretory protein of the gland could be tubular or acinar.

C. According to the nature of secretion:

a. Serous: e.g. pancreatic acini, parotid salivary gland and lacrimal glands.
b. Mucous: e.g. sublingual salivary gland.
c. Mixed: e.g. submandibular salivary glands.

Q. What are the apical structures of epithelial cells?

Ans.: They are:

1) Microvilli are small membrane projections with cores of actin filaments that generally function to increase epithelial cell's apical surface area for absorption.
2) Stereocilia are long microvilli with specialized mechanosensory function in cells of the inner ear and for absorption in tissues of the male reproductive tract.
3) Cilia are larger projecting structures with a well-organized core of microtubules (in a 9+2 arrangement called the axoneme) in which restricted dynein-based sliding of microtubules causes ciliary movement that propel material along an epithelial surface.

Q. What are the intercellular adhesion and other junctions?

Ans.:

1) Tight or occluding junctions (zonulae occludens) form a seal between adjacent cells.
2) Adherent or anchoring junctions are sites of string cell adhesion (zonula adherens). A related adherent junction is the desmosome or macula adherens.
3) Gap junctions are channels for communication between adjacent cells.

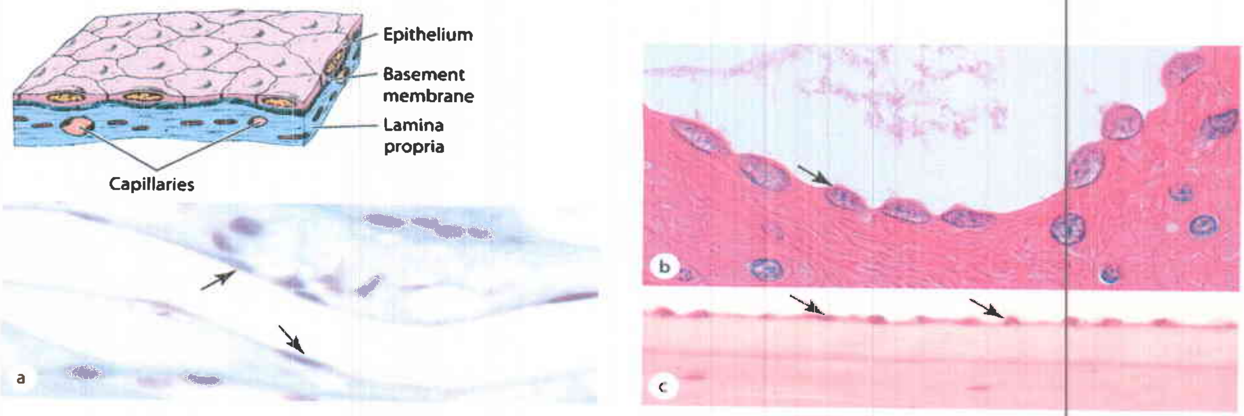


FIGURE 2.1

Figure 2.1 Simple squamous epithelium:

This is a single layer of thin cells, in which the cell nuclei (arrows) are the thickest and most visible structures. Simple epithelia are typically specialized as lining of vessels and -cavities, where they regulate passage of substances into the underlying tissue. The thin cells often exhibit transcytosis. Examples shown here are those lining the thin renal loops of Henle (a), covering the outer wall of the intestine (b), and lining the inner surface of the cornea (c). a, c X400; b X600. H&E.

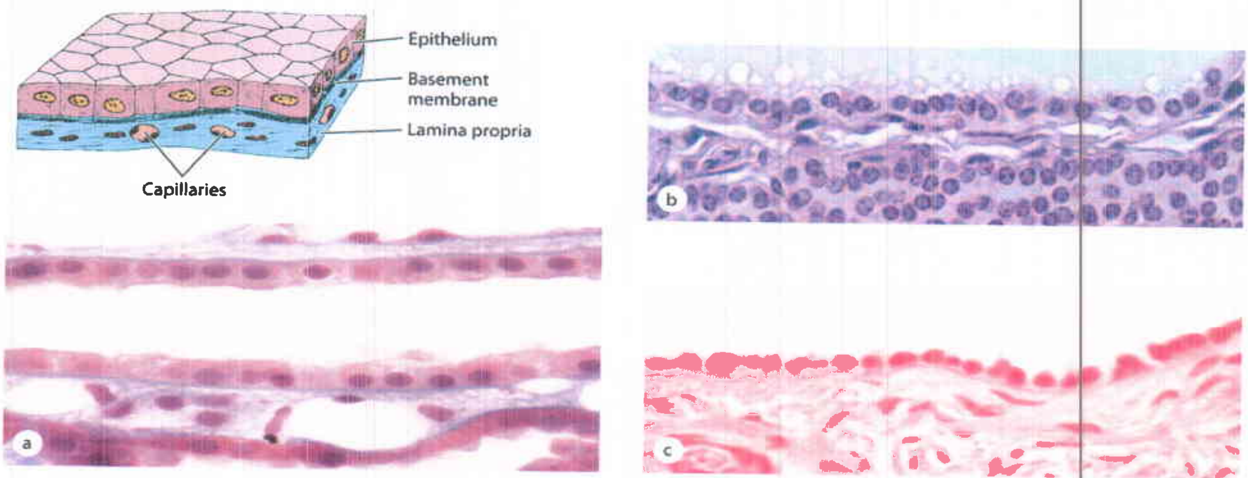


FIGURE 2.2

Figure 2.2 Simple cuboidal epithelium:

Cells here are roughly as tall as they are wide. Their greater thickness allows cytoplasm to be rich in mitochondria and other organelles for a high level of active transport across the epithelium and other functions. Examples shown here are from a renal collecting tubule (a), a large thyroid follicle (b), and the thick mesothelium covering an ovary (c). All X400. H&E.

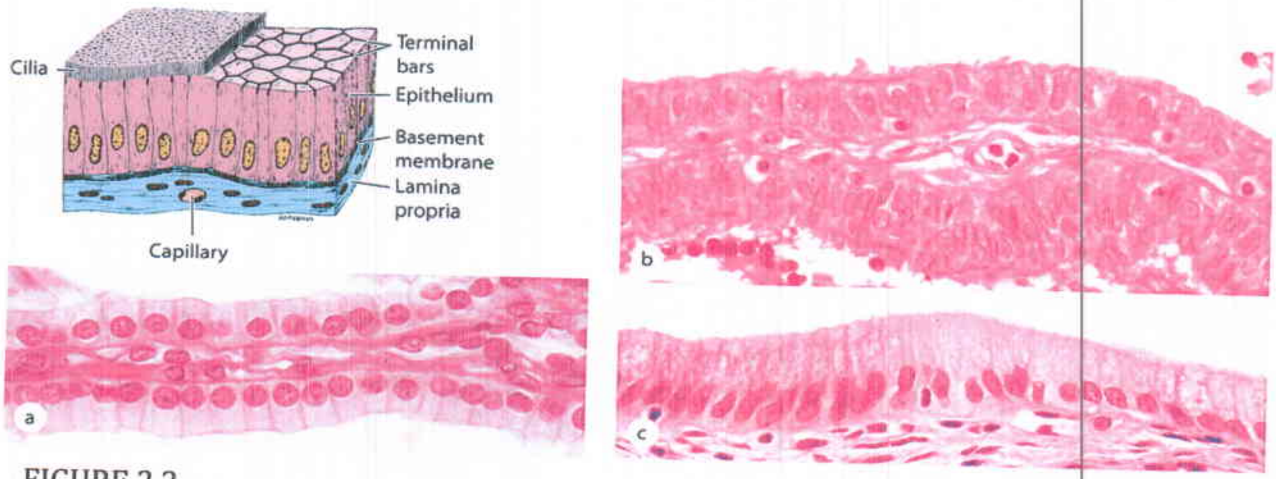


FIGURE 2.3

Figure 2.3 Simple columnar epithelium:

Cells here are always taller than they are wide, with apical cilia or microvilli, and are often specialized for absorption. Complexes of tight and adherent junctions, sometimes called "terminal bars" in light microscopic images, are present at the apical ends of cells. The examples shown here are from a renal collecting duct (a), the oviduct lining, with both secretory and ciliated cells (b), and the lining of the gall bladder (c). All X400. H&E.

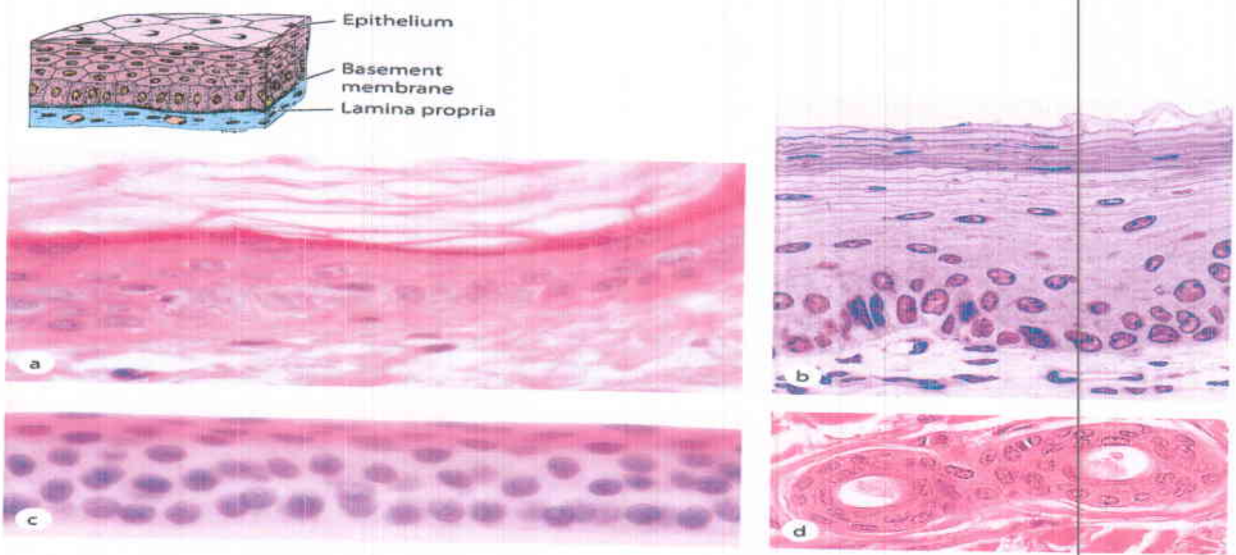


FIGURE 2.4

Figure 2.4 Stratified epithelium:

Stratified squamous epithelia usually have protective functions: protection against easy invasion of underlying tissue by microorganisms and protection against water loss. These functions are particularly important in the epidermis (a) in which differentiating cells become keratinized, ie, filled with keratin and other substances, eventually lose their nuclei and organelles, and form superficial layers flattened squames that impede water loss. Keratinized cells are sloughed off and replaced by new cells from more basal layers, which are discussed fully with the skin in Chapter 18.

Nonkeratinized epithelia occur in many organs, such as the esophageal lining (b) or outer covering of the cornea (c). Here cells accumulate much less keratin and retain their nuclei but still provide protection against microorganisms.

Stratified cuboidal or columnar epithelia are fairly rare but occur in excretory ducts of certain glands, such as sweat glands (d) where the double layer of cells allows additional functions. All X400; (b) PT, (a, c, and d) H&E.

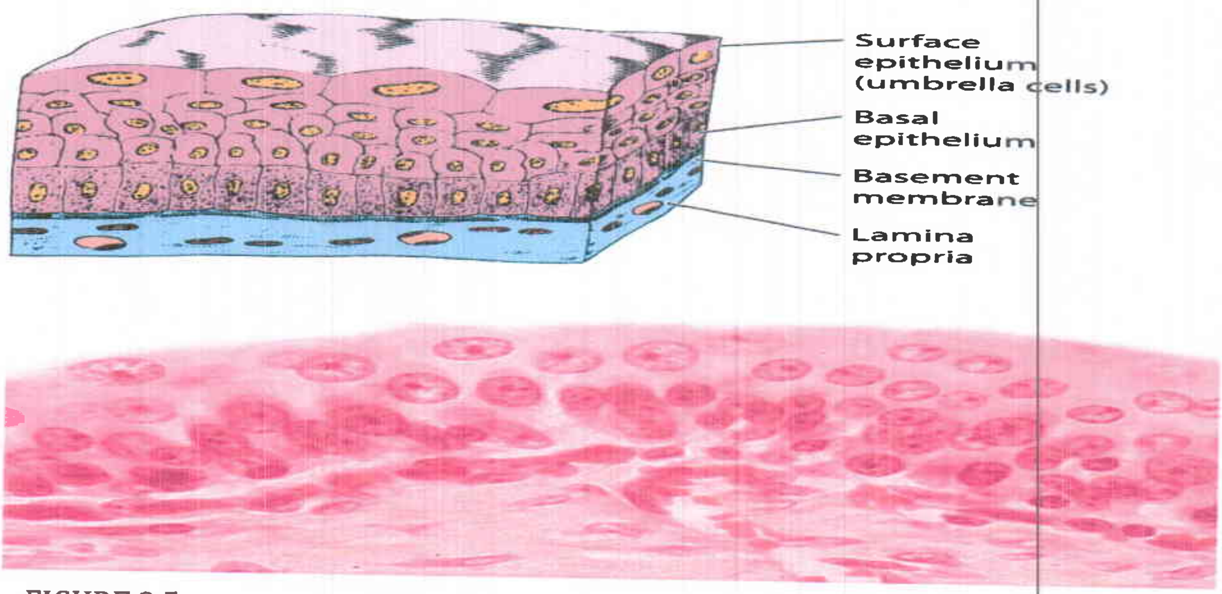


FIGURE 2.5

Figure 2.5 Transitional epithelium or urothelium:

Urothelium is stratified and lines much of the urinary tract. The superficial cells are rounded or dome-shaped, and have specialized membrane features enabling them to withstand the hypertonic effects of urine and protect underlying cells from this toxic solution. Cells of this epithelium are also able to adjust their relationships with one another and undergo a transition in their appearance as the urinary bladder fills and the wall is distended. These unique features of transitional epithelium are discussed more extensively in Chapter 19. X400. H&E.

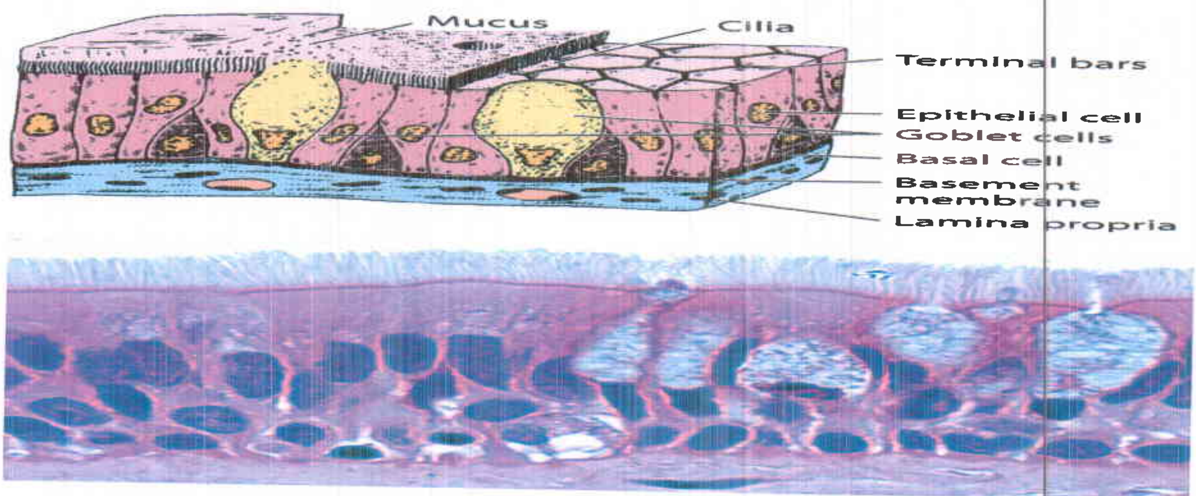
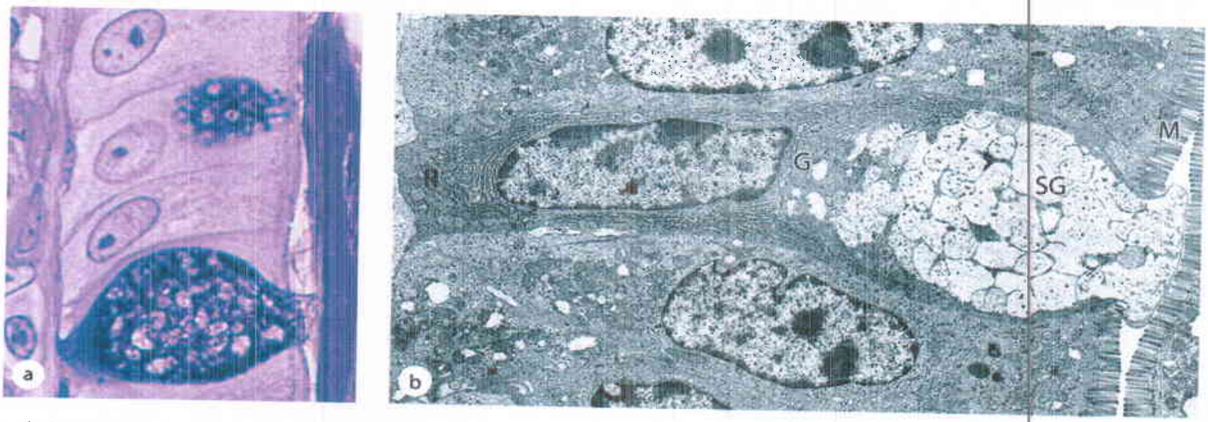


FIGURE 2.6

Figure 2.6 Pseudostratified epithelium:

Cells of pseudostratified epithelia appear to be in several layers, but their basal ends all rest on the basement membrane. The pseudostratified columnar epithelium of the upper respiratory tract shown here contains many ciliated cells, as well as other cells with their



nuclei at different levels. X400. H&E.

Figure 2.7 Goblet cells: unicellular glands:

The simple columnar epithelium lining the large intestine shows many isolated goblet cells secreting mucus into the lumen. (a) With a stain for the oligosaccharide components of mucin glycoproteins, the cytoplasmic secretory granules of two goblet cells and secreted mucus are stained purple. X600. PAS-PT. (b) As shown ultrastructurally, goblet cells always have basal nuclei surrounded by RER (R), a large Golgi complex (G), and abundant apical cytoplasm filled with large secretory granules (SG). After exocytosis mucin components are hydrated and become mucus. A brush border of microvilli (M) is seen on neighboring columnar cells.

FIGURE 2.7

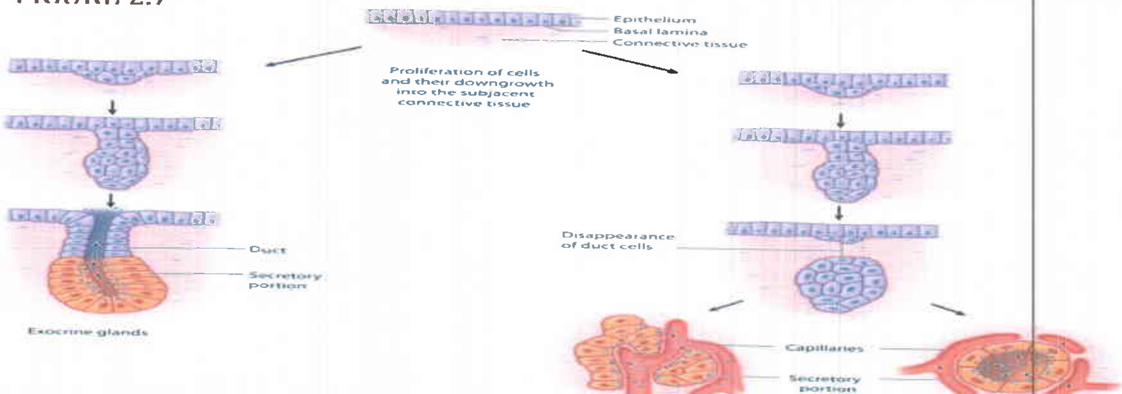


FIGURE 2.8

X17,000.

Figure 2.8 Formation of glands from covering epithelia:

During fetal development epithelial cells proliferate and penetrate the underlying connective tissue. These cells may—or may not—maintain a connection with the surface epithelium. The connection is maintained to form a duct in exocrine glands; it is lost as endocrine glands develop. Exocrine glands secrete substances to specific organs via duct systems. Endocrine glands produce hormones and are always rich in capillaries.

Hormones are released outside the cells and picked up by these blood vessels for distribution throughout the body, where specific target cells are identified by receptors for the hormones. Endocrine glands can have secretory cells arranged as irregular cords (left) or as rounded follicles (right) with lumens for temporary storage of the secretory product.

3- Connective Tissue

Q. What is connective tissue?

Ans.: Connective tissues originate from embryonic mesenchyme, a tissue developing mainly from the middle layer of the embryo, the mesoderm.

Q. What are the functions of connective tissues?

Ans.: Connective tissues maintain the form of organs throughout the body. They provide a matrix that supports and physically connects other tissues of cells together in organs. Interstitial fluid of connective tissue gives metabolic support to cells as the medium for diffusion of nutrients and waste products.

Q. What are the cells and their functions in connective tissues?

Ans.:

1) Fibroblasts: Synthesize and secrete collagen and elastin, as well as the GAGS, proteoglycans, and multi-adhesive glycoproteins that comprise the ground substance.
2) Adipocytes or Fat cells: Specialized for cytoplasmic storage of lipid as neutral fats, or less commonly for the production of heat. The large deposits of fat in the cells of adipose connective tissue also serve to cushion and insulate the skin and other organs.
3) Macrophages: Characterized by their well-developed phagocytic ability and specialize in turnover of protein fibers and removal of dead cells, tissue debris, or other particulate material.
4) Mast cells: Function in the localized release of many biochemical substances with roles in the local inflammatory responses, innate immunity, and tissue repair. These substances include heparin, histamine, serine proteases, eosinophil and neutrophil chemotactic factors, cytokines, and phospholipid.
5) Plasma cells: These are B-lymphocytes-derived, antibody-producing cells.
6) Leukocytes: Called white blood cells and make up a population of wandering cells in connective tissue.

Q. What are the fibrous components of connective tissue?

Ans.: The three main types of fibers include collagen, reticular and elastic fibers. Collagen is the most abundant protein in the human body; representing 30% of its dry weight. A major product of fibroblasts, collagens are secreted by several other cell types and are distinguishable by their molecular compositions, morphologic characteristics, distribution, functions, and pathologies. A family of 28 collagens exists in vertebrates, the most important of which are:

1) Fibril-forming collagens (Types I, II, III, V, XI).
2) Sheet-forming collagens (Type IV).
3) Linking-Anchoring collagens (Types VII, IX, XII, XIV).

Fibroblasts secrete collagen in the form of tropocollagen. Tropocollagen consists of 3 polypeptide chains bound together to form a helical structure of 1.5 nm diameter and 260nm length. In extracellular matrix, tropocollagen molecules polymerize to form collagen of different types. Reticular fibers consist mainly of collagen type III. This collagen forms an extensive network (reticulum) of very thin fibers.

Elastic fibers have elastic properties similar to those of rubber, allowing tissues to be stretched or distended and return to their original shape.

Q. What are the constituents of ground substance of connective tissue?

Ans.: The ground substance is a highly hydrated, transparent, complex mixture of macromolecules, principally of three classes: glycosaminoglycans (GAGS), proteoglycans, and multi-adhesive glycoproteins. GAGS (also called mucopolysaccharides) include glucosamine (galactosamine), glucuronic (iduronic) acid, hyaluronic acid, dermatan sulfate, chondroitin sulfates, keratin sulfate and heparin sulfate.

Q. What are the types of connective tissue?

Ans.:

1) Connective tissue proper.
   a) Loose connective tissue (also called areolar tissue) is very common and generally supports epithelial tissue.
   b) Dense connective tissue is adapted to offer stress resistance and protection.
2) Reticular tissue.
   In reticular tissue fibers of type III collagen form a delicate 3D network supports various types of cells.
3) Mucoid (or Mucous) connective tissue.
   This is an embryonic type of connective tissue, found mainly in the umbulical cord and fetal organs.

Q. What is adipose tissue?

Ans.: Connective tissue in which adipocytes or fat cells predominate is commonly called adipose tissue. These large cells are found isolated or in small groups within loose or dense irregular connective tissue but occur in large aggregates as adipose tissue or fat in many body regions and organs. Adipocytes release hormones and various other important substances, and adipose tissue is now recognized as an important endocrine tissue.

Q. What is meant by white adipose tissue?

Ans.:

1) This tissue is found in many organs throughout the body, typically forming about 20% of the body weight in adults.
2) Adipocytes of white fat are typically very large cells, ranging in diameter from 50 to 150 um.
3) Each of these cells contain primarily one large lipid droplet (they are unilocular), causing the nucleus and remaining cytoplasm to be pushed against the plasma-lemma.
4) Fatty acids are released from white adipocytes when nutrients are needed and carried throughout the body on plasma proteins such as albumin.

Q. What is meant by brown adipose tissue?

Ans.:

1) It comprises up to 5% of the newborn body weight.
2) Adipocytes of this tissue are typically smaller than those of white fat and contain primarily many small lipid droplets (they are multi-locular) in cytoplasm containing many mitochondria and a central nucleus.
3) The color of brown adipose tissue or brown fat is due to both the very abundant mitochondria (containing cytochrome pigment) and the large number of blood capillaries in this tissue.
4) Fatty acids released in adipocytes of brown fat are metabolized in mitochondria of these cells for thermogenesis (heat production).

Q. What is a cartilage?

Ans.:

1) Cartilage is a tough, flexible form of connective tissue, characterized by an extracellular matrix (ECM) with high concentrations of GAGS and proteoglycans, which interact with collagen and elastic fibers.
2) Cells of cartilage, chondrocytes, make up a small percentage of tissue's mass, which is mainly a flexible mass of ECM.
3) Chondrocytes are embedded within cavities (lacunae) surrounded by the ECM.
4) Cartilage always lacks blood vessels, lymphatic, and nerves, but it is usually surrounded by a dense connective tissue perichondrium that is vascularized.
5) There are three major forms of cartilage: (1) hyaline cartilage, (2) elastic cartilage, and (3) fibrocartilage.

Q. What are the features of various forms of cartilage?

Ans.:

Hyaline cartilage: ECM is homogenous and glassy, rich in fibrils of type II collagen. Chondrocytes occur singly or in small isogenous groups. Perichondrium is usually present.

Elastic cartilage: Its matrix includes abundant elastic fibers and it is always surrounded by perichondrium.

Fibrocartilage: Consists of small chondrocytes in a hyaline matrix, usually layered with larger areas of bundled type **I** collagen with scattered fibroblasts.

Q. What is a bone?

Ans.: Bone is a type of connective tissue with a calcified extracellular matrix (ECM), specialized to support the body, protect many internal organs, and act as the body's Ca^{2+} reservoir.

Q. What are the major cells and matrix components of bone?

Ans.:

1) Osteoblasts differentiate from (stem) osteoprogenitor cells and secrete components of the initial matrix, called osteoid, that allow matrix mineralization to occur.
2) Important component of osteoid include type **I** collagen, the protein osteocalcin, which binds Ca^{2+} and matrix vesicles with enzymes generating Po_4-.
3) High concentrations of Ca^{2+} and Po_4- ions cause formation of hydroxyapatite crystals, whose growth gradually calcifies the entire matrix.
4) Osteocytes differentiate further from osteoblasts when they become enclosed within matrix lacunae and act to maintain the matrix and detect mechanical stresses on bone.
5) Osteocytes maintain communication with adjacent cells via a network of long dendritic processes that extend through the matrix via narrow canaliculi radiating from each lacuna.
6) Osteoclasts are very large cells, formed by fusion of several blood monocytes, which locally erode bone matrix during osteogenesis and bone remodeling.

Q. What is meant by periosteum and endosteum?

Ans.: Periosteum is a layer of dense connective tissue on the outer surface of bone, bound to bone matrix by bundles of type I collagen called perforating (or sharpey) fibers. Regions of periosteum adjacent to bone are rich in osteoprog-enitor cells and osteoblasts that mediate increases in bone thickness by appositional growth.

The endosteum is a thin layer of active and inactive osteoblasts, which lines all the internal surfaces within bone; osteoblasts here are also required for bone growth.

Q. What are the types and organization of bones?

Ans.:

1) Compact (cortical) bone, which represents 80% of the total bone mass, and deeper areas with numerous interconnecting cavities, called cancellous (trabecular or spongy) bone.
2) In long bones, the bulbous ends-called epiphyses are composed of spongy bone covered by a thin layer of compact bone. The cylindrical part-the diaphysis is almost totally composed of compact bone, with a thin region of spongy bone on the inner surface around the central marrow cavity.

Q. What is an osteon?

Ans.:

An osteon (or Haversion system) refers to the complex of concentric lamellae surrounding a small central canal that contains blood vessels, nerves loose connective tissue, and endosteum. Between successive lamellae are lacunae, each with one osteocyte, interconnected by canaliculi containing the cell's dendritic processes. Each osteon consists of a central canal surrounded by 4-10 concentric lamellae. The central canal communicate with the narrow cavity and the periosteum and with one another through transverse perforating canals (or Volkmann canals).

Q. How bone development or osteogenesis occurs?

Ans.:

Bone development or osteogenesis occurs by one of two ways:

1) Intramembranous ossification, in which osteoblasts differentiate directly from mesenchyme and begin secreting osteoid.
2) Endochondral ossification, in which a preexisting matrix of hyaline cartilage is eroded and invaded by osteoblasts, which then begin osteoid production.

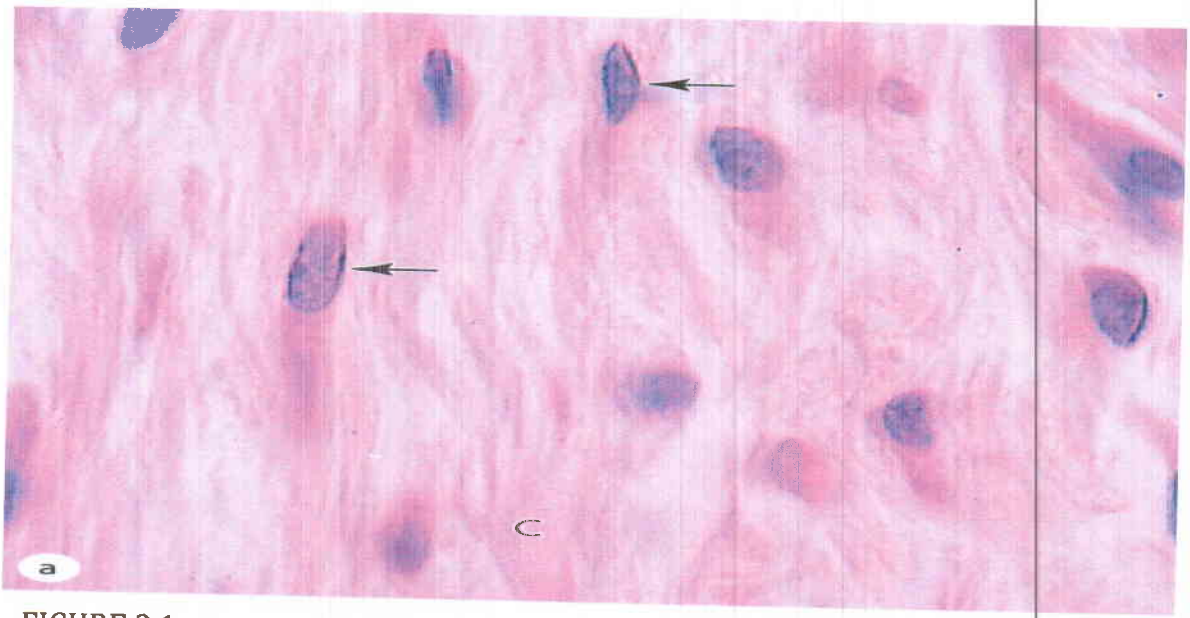


FIGURE 3.1

Figure 3.1 Fibroblasts:

(a) Fibroblasts typically have large active nuclei and eosinophilic cytoplasm that tapers off in both directions along the axis of the nucleus, a morphology often referred to as "spindle-shaped." Nuclei (arrows) are clearly seen, but the eosinophilic cytoplasmic processes resemble the collagen bundles (C) that fill the ECM and are difficult to distinguish in H&E-stained sections.

(b) Both active and quiescent fibroblasts may sometimes be distinguished, as in this section of dermis. Active fibroblasts have large, euchromatic nuclei and basophilic cytoplasm, while inactive fibroblasts (or fibrocytes) are smaller with more heterochromatic nuclei (arrows). The round, very basophilic round cells are in leukocytes. Both X400. H&E.

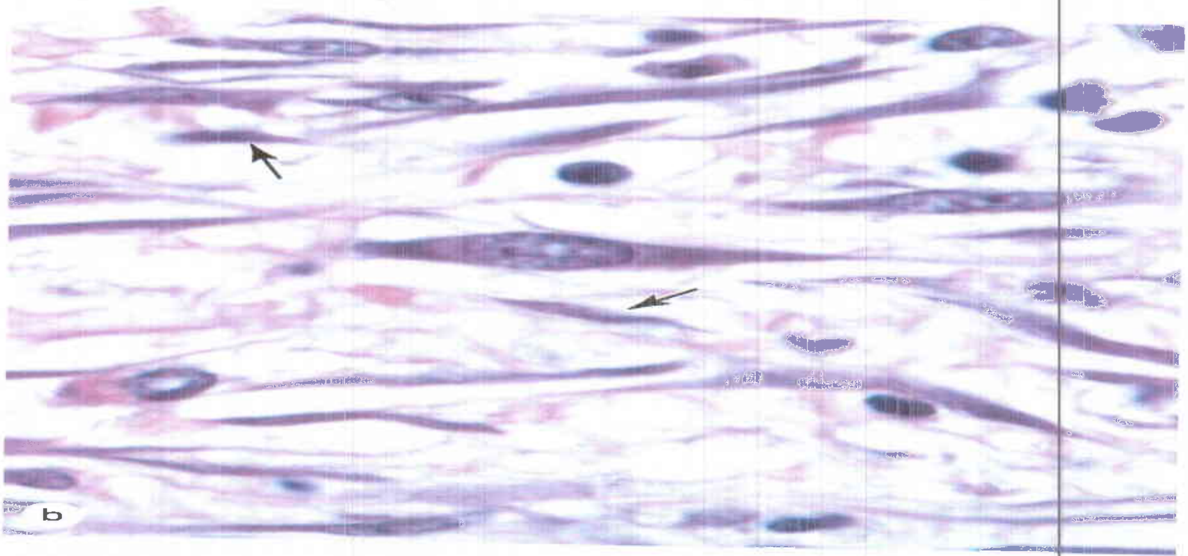


FIGURE 3.2

Figure 3.2 Fibroblasts:

(a) Fibroblasts typically have large active nuclei and eosinophilic cytoplasm that tapers off in both directions along the axis of the nucleus, a morphology often referred to as "spindle-shaped.

" Nuclei (arrows) are clearly seen, but the eosinophilic cytoplasmic processes resemble the collagen bundles (C) that fill the ECM and are difficult to distinguish in H&E-stained sections.

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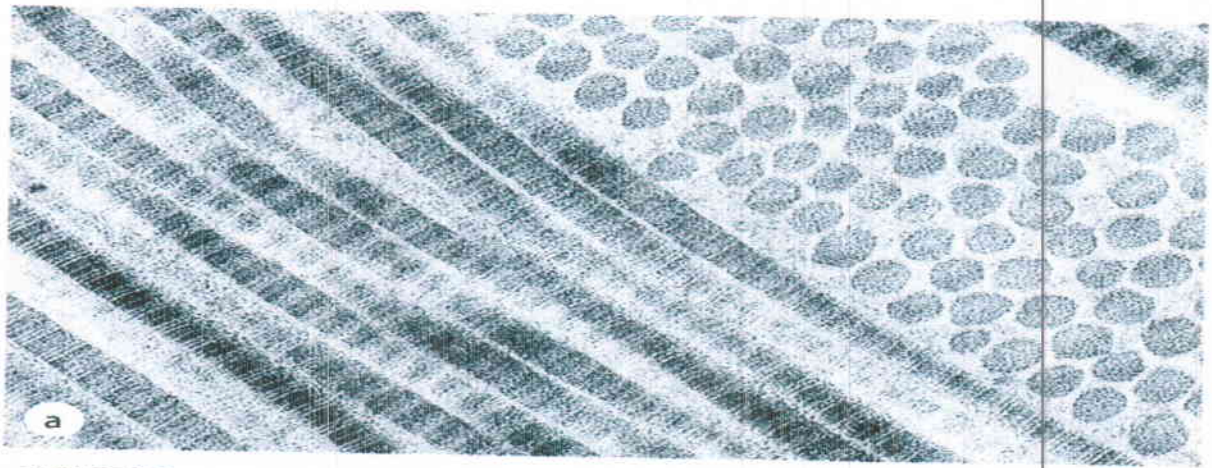

FIGURE 3.3

Figure 3.3 Type I collagen:

Subunits of type I collagen, the most abundant collagen, assemble to form extremely strong fibrils, which are then bundled together further by other collagens into much larger structures called collagen fibers.

(a) TEM shows fibrils cut longitudinally and transversely. In longitudinal sections fibrils display alternating dark and light bands; in cross section the cut ends of individual collagen molecules appear as dots. Ground substance completely surrounds the fibrils. X100,000.

(b) The large bundles of type I collagen fibrils (C) appear as acidophilic collagen fibers in connective tissues, where they may fill the extracellular space. Subunits for these fibers were secreted by the fibroblasts (arrows) associated with them. X400. H&E.

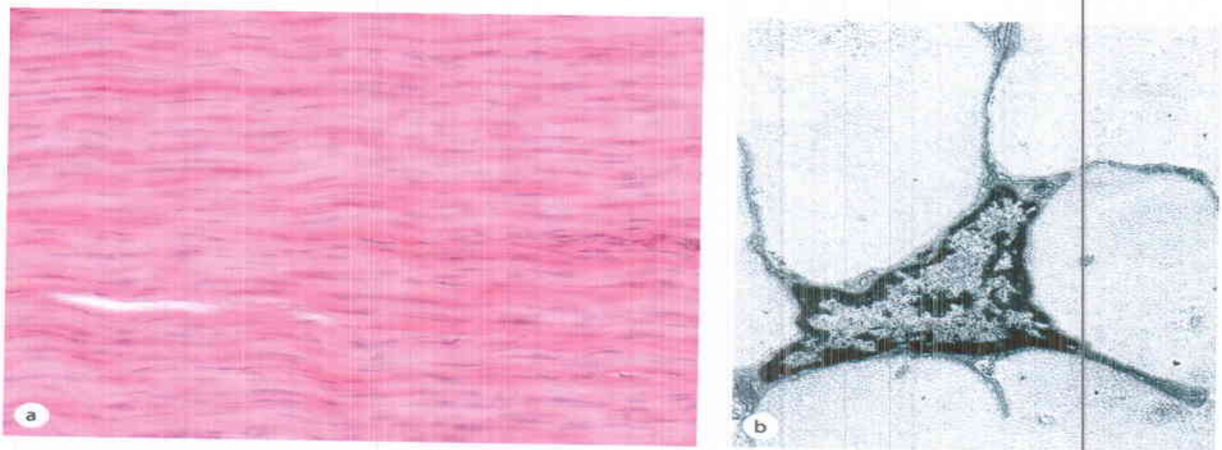

FIGURE 3.4

Figure 3.4 Dense regular connective tissue:

(a) Micrograph shows a longitudinal section of dense regular connective tissue in a tendon. Long, parallel bundles of collagen fibers fill the spaces between the elongated nuclei of fibrocytes. X100. H&E stain.

(b) The electron micrograph shows one fibrocyte in a cross section of tendon, revealing that the sparse cytoplasm of the fibrocytes is divided into numerous thin cytoplasmic processes extending among adjacent collagen fibers. X25,000.

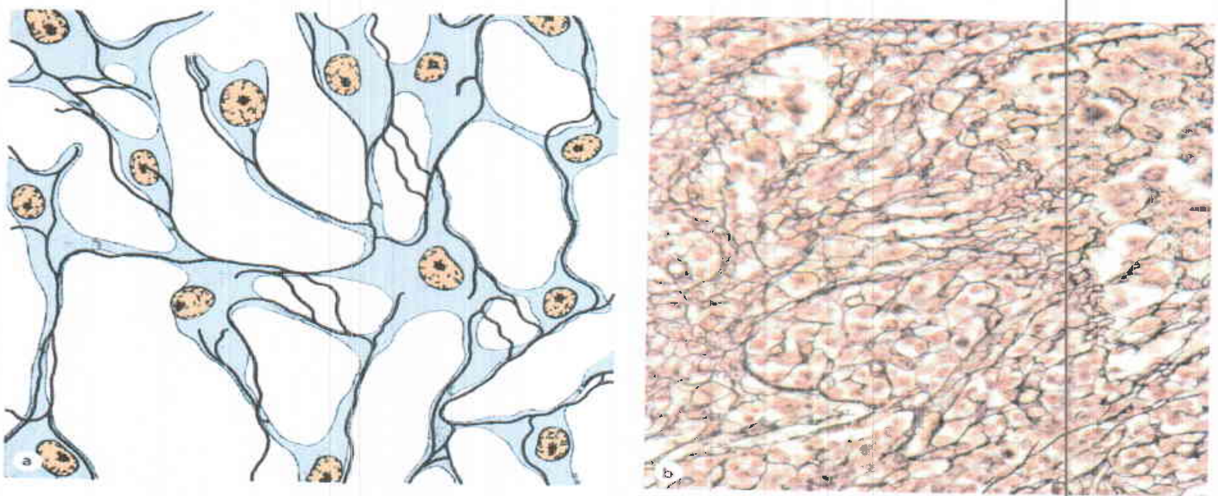

FIGURE 3.5

Figure 3.5 Reticular tissue:

(a) The diagram shows only the fibers and attached reticular cells (free, transient cells are not represented). Reticular fibers of type III collagen are produced and enveloped by the reticular cells, forming an elaborate network through which interstitial fluid or lymph and wandering cells from blood pass continuously.

(b) The micrograph shows a silver-stained section of lymph node in which reticular fibers are seen as irregular black lines. Reticular cells are also heavily stained and dark. Most of the smaller, more lightly stained cells are lymphocytes passing through the lymph node. X200. Silver.

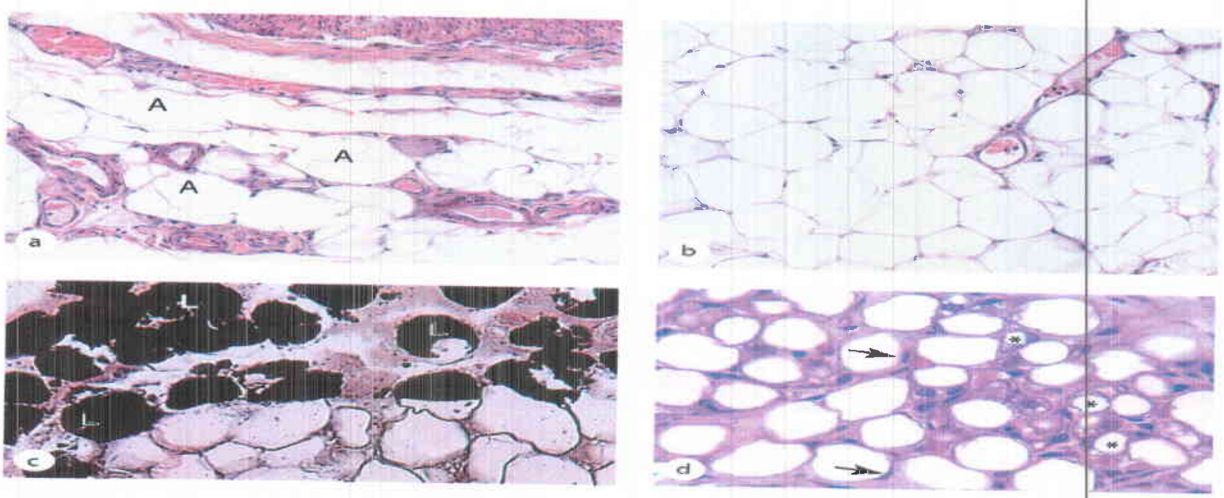

FIGURE 3.6

Figure 3.6 White adipose tissue:

White or unilocular adipose tissue is commonly seen in sections of many human organs. (a) Large white adipocytes (A) are seen in the connective tissue associated with small blood vessels. The fat cells are empty because lipid was dissolved away in slide preparation. Nuclei at the cell membranes are visible in some of the fat cells. X100. H&E.

(b) Large (empty) adipocytes predominate in this typical white adipose tissue, which shows only a small portion of microvasculature. In a single histologic section, nuclei of most very large adipocytes are not included. X100. H&E.

(c) Tissue was fixed here with osmium tetroxide, which preserves lipid (L) and stains it black. Many adipocytes in this slide retain at least part of their large lipid droplets. X440. Osmium tetroxide.

(d) The specimen here was from a young mammal, and the adipocytes marked with asterisks are not yet unilocular, having many small lipid droplets in their cytoplasm, which indicates that their differentiation is not yet complete. The eccentric nuclei of unilocular cells are indicated by arrowheads. X200. PT.

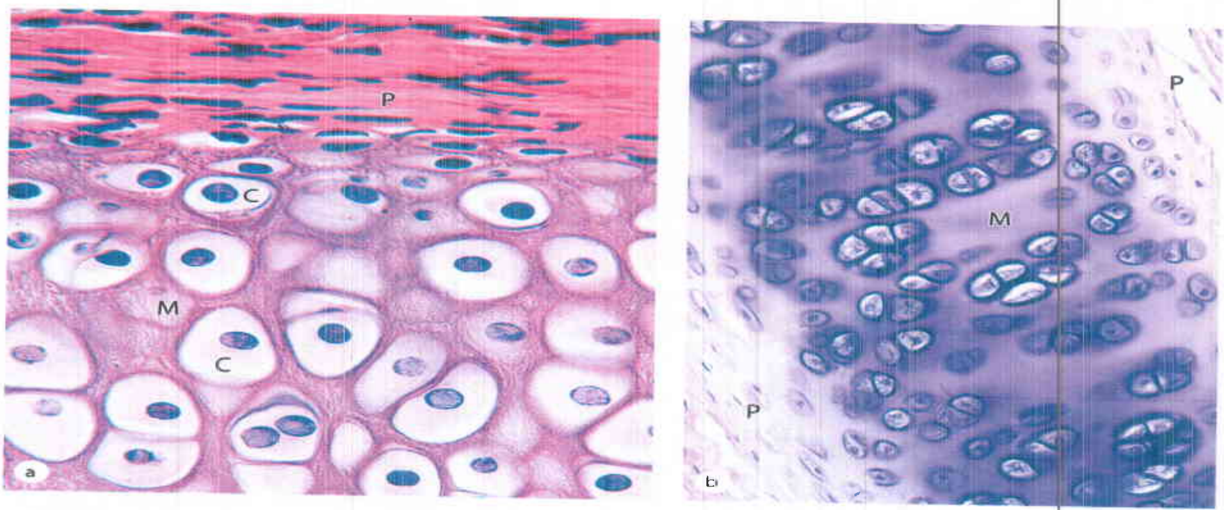

FIGURE 3.7

Figure 3.7 Hyaline cartilage:

(a) The upper part of the photo shows the more acidophilic perichondrium (P), an example of dense connective tissue consisting largely of type I collagen. There is a gradual transition and differentiation of cells from the perichondrium to the cartilage, with elongated fibroblastic cells becoming larger and more rounded chondroblasts and chondrocytes (C) located within spaces or lacunae surrounded by the matrix (M) secreted by the cells. X200. H&E.

(b) The thin region of hyaline cartilage shown here has perichondrium (P) on both sides and shows larger lacunae containing isogenous groups of chondrocytes (C) within the matrix (M). Such groups of two, four, or more cells are produced by mitosis; the cells will separate into individual lacunae as they begin to secrete matrix. X160. H&E.

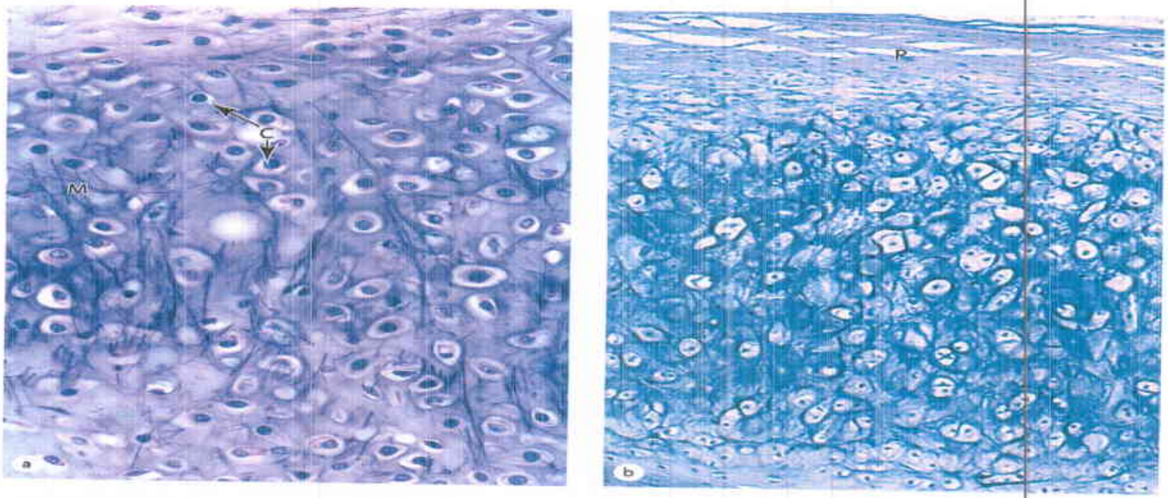

FIGURE 3.8

Figure 3.8 Elastic cartilage:

The chondrocytes (C) and overall organization of elastic cartilage are similar to those of hyaline cartilage. Stains for elastin, however, reveal many dark-staining elastic fibers in the matrix (M), in addition to the major components found in hyaline matrix. Elastic fibers provide greater flexibility to this form of cartilage. The section in part b includes perichondrium (P) that is also similar to that of hyaline cartilage. (a) X160. Hematoxylin and orcein. (b) X100. Weigert resorcin-fuchsin.

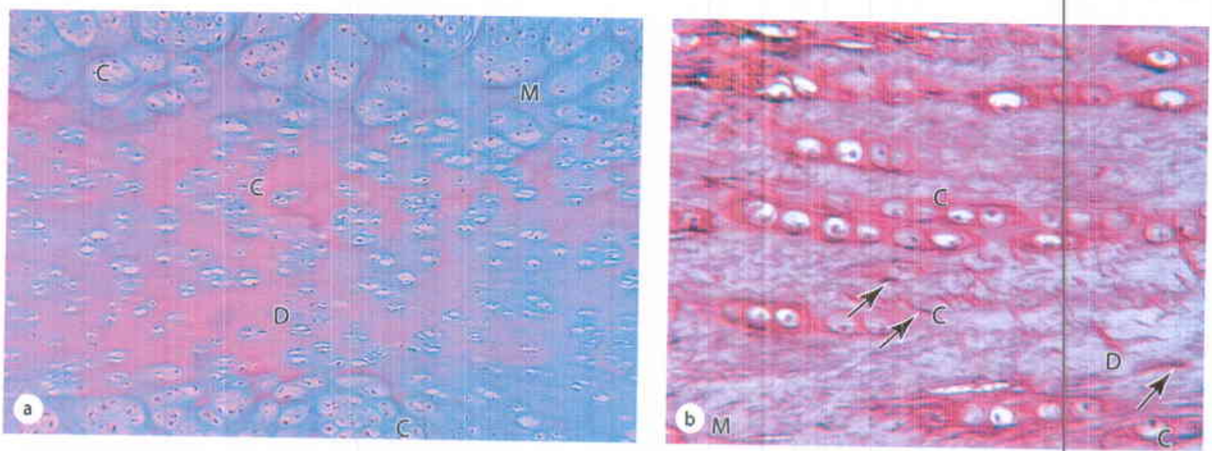

FIGURE 3.9

Figure 3.9 Fibrocartilage:

Fibrocartilage varies in different organs, but is essentially a mixture of hyaline cartilage and dense connective tissue.

(a) A section of pubic symphysis shows lacunae with isolated and grouped chondrocytes (C) surrounded by matrix (M) and separated in some areas by dense regions (D) containing more concentrated acidophilic type I collagen. No separate perichondrium is present on fibrocartilage. X100. H&E.

(b) At higher magnification in a small region of intervertebral disc, the axially arranged aggregates of chondrocytes (C) are seen to be surrounded by small amounts of matrix and separated by larger regions with dense collagen (D) and a small number of fibroblasts with elongated nuclei (arrows). X250. Picrosirius-hematoxylin.

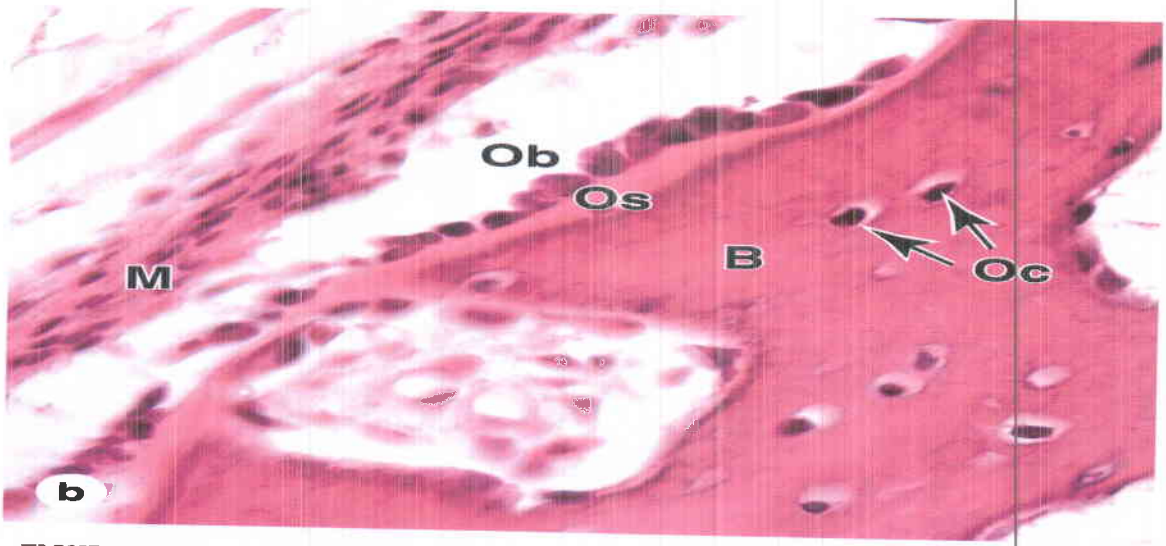

FIGURE 4.1

Figure 4.1 Osteoblasts and osteocytes:

(a) Diagram showing the relationship of osteoblasts to osteoid, bone matrix, and osteocytes. Osteoblasts and most of the larger osteoclasts are part of the endosteum covering the bony trabeculae.

(b) The photomicrograph of developing bone shows the location and morphologic differences between active osteoblasts (Ob) and osteocytes (Oc). Rounded osteoblasts, derived from cells in the adjacent mesenchyme (M), appear as a layer of cells adjacent to a very thin layer of lightly stained osteoid (Os) that covers the more heavily stained bony matrix (B). Inactive osteoblasts are more flattened and cover the bony surface shown near the top here. Osteocytes are located within lacunae surrounded by matrix. X300. H&E.

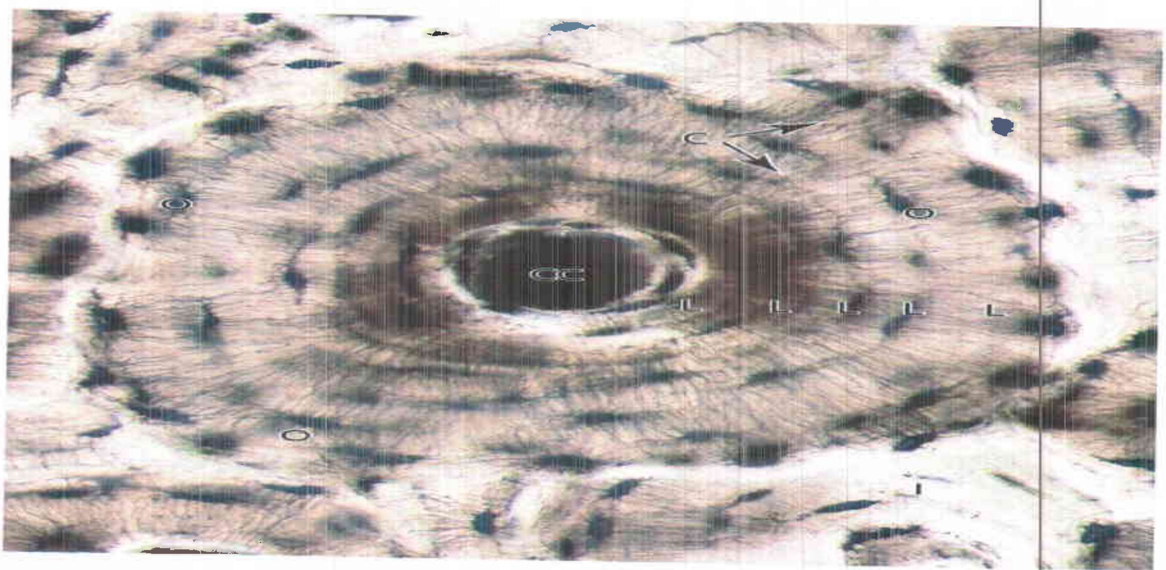

FIGURE 4.2

Figure 4.2 An osteon:

Osteons (Haversian systems) constitute most of the compact bone. Shown here is an osteon with four to five concentric lamellae (L) surrounding the central canal (CC). Osteocytes (O) in lacunae are in communication with each other and with the central canal and periphery of the osteon via through hundreds of dendritic processes located within fine canaliculi (C). Also shown are the partial, interstitial lamellae (I) of an osteon partially eroded when the intact osteon was formed. Ground bone. X500.

4- Muscle Tissue

Q. What are the types of muscle tissue?

Ans.: They are three types:

1) Skeletal muscle (striated, striped, voluntary muscle) contains bundles of very long, multi-nucleated cells with cross-striations. Their contraction is quick, forceful, and usually under voluntary control.
2) Cardiac muscle also has cross-striations and is composed of elongated, often branched cells bound to one another at structures called intercalated discs that are unique to cardiac muscle. Contraction is involuntary, vigorous, and rhythmic.
3) Smooth muscle consists of collections of fusiform cells that lack striations and have slow, involuntary contractions.

Q. What are the connective tissues present in a muscle?

Ans.:

1) Endomysium: in between muscle fibers.
2) Perimysium: in between fasciculi (bundle of muscle fibers).
3) Epimysium: surrounding whole muscle.

Q. What could be the length of a muscle fiber?

Ans.:

1) A striated muscle fiber (a myocyte) is as long as the length of the muscle from its origin to insertion i.e. it could be about 35 cm in the case of Sartorius muscle of thigh.
2) A smooth muscle fiber is about 15 μ to 300 μ.
3) A cardiac muscle fiber is 80 μ long and 15 μ in diameter.

Q. What are the differences regarding their nuclei in the three types if muscle fibers?

Ans.:

1) A skeletal muscle fiber may have 200-300 nuclei, peripherally situated near the sarcolemma.
2) A smooth muscle fiber has only one nucleus, which makes a bulge at the center of muscle fiber.
3) A cardiac muscle has 1 or 2 nuclei in the center.

Q. What are the contractile proteins in a muscle?

Ans.:

Actin, myosin and tropomyosin are the contractile proteins found in muscle. They are synthesized by myoblasts. The cross striations are the result of arrangement of these muscle proteins. Myosin are thick filaments supported at M band. Actin are thin filaments supported in a disc- like zone named Z band. During contraction of a muscle fiber, thick and thin filaments slide over each other under the influence of energy released from ATP.

Q. What are the different types of muscle fibers in a skeletal muscle?

Ans.:

1) Red fibers: Slow, small, rely on aerobic respiration, more myoglobin. Also called type **I** fibers, e.g. leg muscles.
2) White fibers: Fast, rely on anaerobic respiration, large in cross section, low myoglobin, few mitochondria and cytoplasm, e.g. flight birds.

_ Both type **I** and **II** are in various proportions in all muscles.

_ Red muscle fibers predominate in postural muscles required to be in constant activity.

Q. What are the differences between skeletal and visceral muscles in terms of functions?

Ans.:

Skeletal muscles contract for some time with increased force and later they get fatigued. They are innervated by peripheral nervous system upon which they are completely dependent for contraction.

Visceral muscles do not get fatigued in spite of their constant activity. They have a low force of contraction in the form of waves. They are innervated by autonomic nervous system, but they are not completely dependent on innervation for the contraction.

Q. What are intercalated discs (or intercalary discs)?

Ans.:

They are specialized intercellular junctions in cardiac muscle. They permit anchorage for myofibrils and also for rapid spread of contractile stimuli from one cell to another, acting as a functional syncytium. Intercalated discs coincide with Z lines.

Q. What are the different band formations in a skeletal muscle?

Ans.:

Actin = Light Band = l Band = Isotropic (syn. J Band).

Myosin = Dark Band = A Band = Anisotropic (syn. Q).

l Band is traversed by Z line or Krause's membrane in its middle.

A Band is traversed by H band or Hensen's line in its middle.

M Band is in the center of H band.

B_Z line to Z line = a sarcomere _ a.

Z line = Zwischen scheibe.

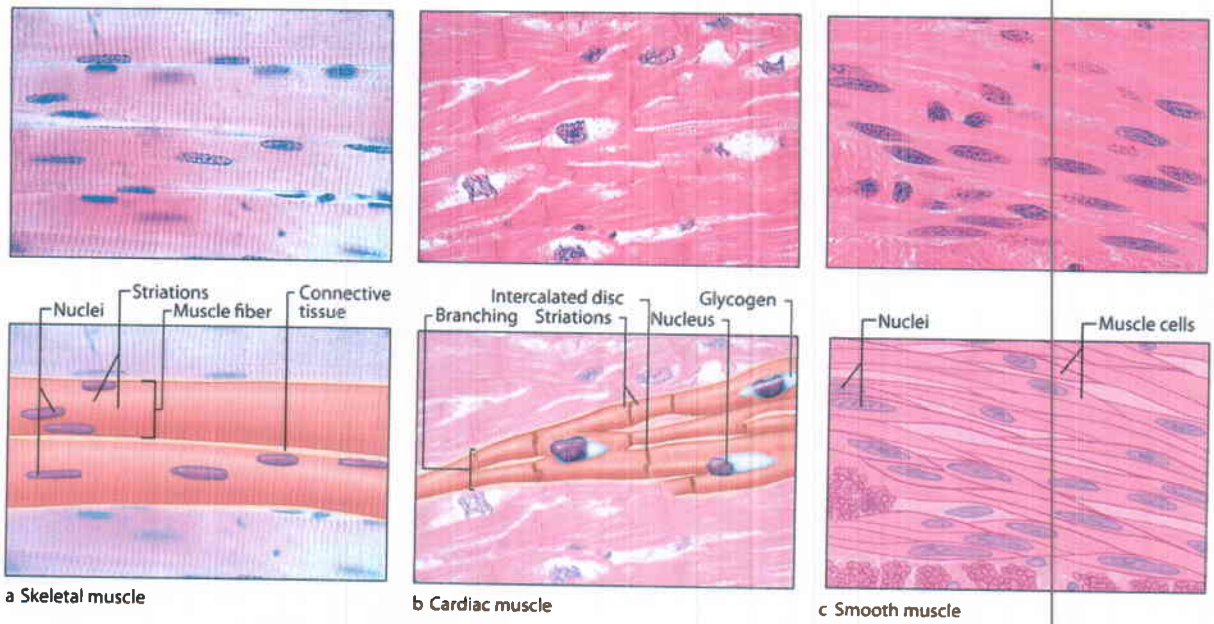

FIGURE 4.3

Figure 4.3 The three types of muscle:

Light micrographs of each type, accompanied by labeled drawings. (a) Skeletal muscle is composed of large, elongated, multinucleated fibers that show strong, quick, voluntary contractions. (b) Cardiac muscle is composed of irregular branched cells bound together longitudinally by intercalated discs and shows strong, involuntary contractions. (c) Smooth muscle is composed of grouped, fusiform cells with weak, involuntary contractions. The density of intercellular packing seen reflects the small amount of extracellular connective tissue present. (a, b): X200. (c): X300. All H&E.

5- Nerve Tissue

Q. What are the types of cells in nerve tissue?

Ans.:

1) Neurons (nerve cells).
2) Glial cells (glia):
   a) Oligodendrocytes.
   b) Astrocytes.
   c) Ependymal cells.
   d) Microglia.
   e) Schwann cells (neurolemmocytes).
   f) Satellite cells.

Q. What are the functions of cells of the nerve tissue?

Ans.:

1) Neurons consist of a cell body (perikaryon) containing the nucleus, a long cytoplasmic extension called the axon, and one or more shorter processes called dendrites. Neurons use the common cell property of excitability to produce and move an action potential (nerve impulse) along the axon to excite another neuron or other effector cell. Such nerve communication is transmitted to another neuron or effector cell via a synapse, where neurotiansmitter is released at the presynaptic membrane and binds receptors on the postsynaptic cell, initiating a new action potential there.
2) Glial cells support neurons in many ways:
   a) Oligodendrocytes wrap processes around portions of axons in the CNS, forming myelin sheaths that insulate the axons and facilitate nerve impulses.
   b) Astrocytes (most numerous cell of the CNS), all produce hundreds of processes to cover and provide regulated microenvironment for neuronal perikarya, synapses, and capillaries.
   c) Ependymal cells line the fluid-filled cerebral ventricles and central canal of the spinal cord.
   d) Microglia mediate the immune defense activity within the CNS.
   e) Schwann cells enclose all axons in nerves of the PNS, producing myelin sheaths around large-diameter axons, whose impulse conductivity is augmented at the nodes of Ranvier between successive Schwann cells.
   f) Satellite cells are located within PNS ganglia, aggregated sensory or autonomic neuronal cell bodies, where they enclose each perikaryon and regulate its environment.

Q. What are the types of neurons?

Ans.:

1) Multi-polar neurons, which have one axon and two or more dendrites.
2) Bipolar neurons, with one dendrites and one axon.
3) Unipolar or pseudounipolar neurons, which have single process that bifurcates close to the perikaryon, with the longer branch extending to a peripheral ending and the other toward the CNS.
4) Axonal (Axonic) neurons, with many dendrites but no true axon, do not produce action potentials, but regulate electrical changes of adjacent neurons.

Q. What is a myelinated nerve fiber?

Ans.:

In PNS, all axons are enveloped by Schwann cells which provide for structure and metabolic support. Large diameter fibers are wrapped by variable number of concentric layers of plasma membrane of Schwann cells. These are myelin sheath and hence the nerves are called myelinated nerves.

Small diameter axons as in autonomic nervous system and small pain fibers are simply enveloped by the cytoplasm of Schwann cells and since there are no concentric layers of plasma membrane (mesaxon) they are said to be nonmyelinated nerve fibers.

Within the CNS, the myelin sheaths are formed by oligodedrocytes (and no by Schwann cells). A single oligodendrocyte can form myelin sheaths for several axons.

The rate of conduction in any nerve fiber is proportional to the diameter of the axons and myelination greatly increases axon conduction velocity compared with that of nonmyelinated fibers of same diameter. All postganglionic fibers are non-myelinated. All preganglionic fibers are myelinated.

Myelin is a lipid material. Myelination begins during foetal development and continues even after birth for some time. It acts like insulator for axon, thus preventing ion fluxes across the plasma membrane of the axon.

Q. What is node of Ranvier?

Ans.:

A Schwann cell producing myelin sheaths covers only a part of nerve axon and their short intervals between Schwann cells at which axon is not covered by a myelin sheath. These are the nodes of Ranvier. This is supposed to aid in "Saltatory conduction" by jumping of action potentials from one node to other-it enhances velocity of conduction. The internodal distance is about 1 mm in largest fiber and is proportional to diameter of fiber.

Q. What is a synapse?

Ans.:

It is a highly specialized inter-neuronal junction-axon to dendrons of next neuron, or to somata of next neuron, etc. when a neuron synapses with skeletal muscle, it is known as motor end plate or neuro-muscular junction. Conduction is always unidirectional, but response could be either excitory or inhibitory. This is mediated by a chemical substance, neurotransmitter, which could be acetylcholine, dopamine, noradrenaline, etc.

Q. What is a ganglion?

Ans.:

Ganglion is discrete aggregation of neuronal cell bodies outside CNS, e.g. spinal ganglion, ganglia associated with some cranial nerves, autonomic ganglia-either sympathetic or parasympathetic.

Q. What is a nucleus in CNS?

Ans.:

Nucleus is aggregation of neuronal cell bodies within CNS, e.g. cranial nerves nuclei, red nucleus, dentate nucleus, anterior horn nucleus, etc.

Q. Optic nerve is not a nerve, but a tract. Comment?

Ans.:

Optic nerve is myelinated, not by Schwann cell, but by oligodendroglia and that is just like any tract in CNS. Optic nerve has no neurilemma sheath. Optic nerve is an extension of forebrain.

Q. What are the connective tissues found in a nerve fiber?

Ans.:

1) Endoneurium: enclosing single nerve fiber.
2) Perineurium: enclosing nerve fasciculus.
3) Epineurium: ensheathing whole nerve.

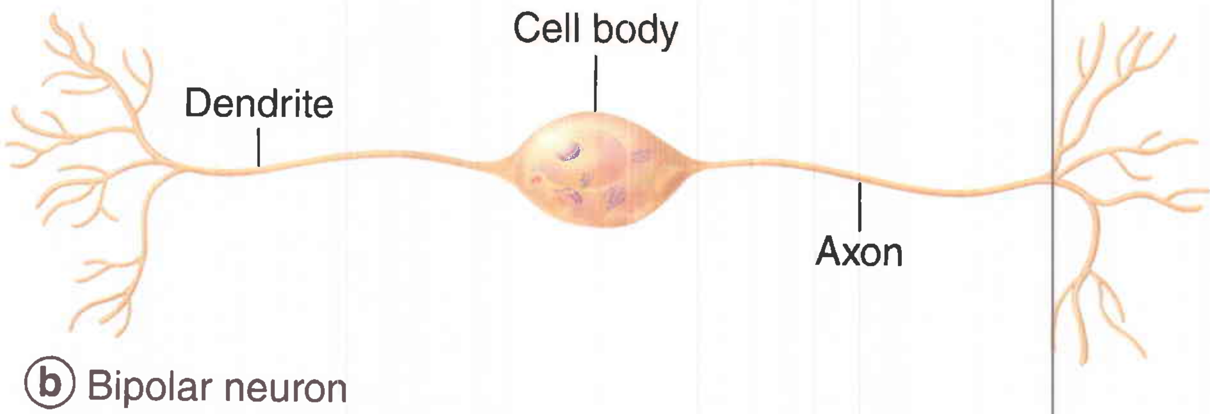

FIGURE 5.1

Figure 5.1 Structural classes of neurons:

Shown are the three main types of neurons, with short descriptions. (a) Most neurons, including all motor neurons and CNS interneurons, are multipolar. (b) Bipolar neurons include sensory neurons of the retina, olfactory mucosa, and inner ear. (c) All other sensory neurons are unipolar or pseudounipolar. (d) Anaxonic neurons of the CNS lack true axons and do not produce action potentials, but regulate local electrical changes of adjacent neurons.

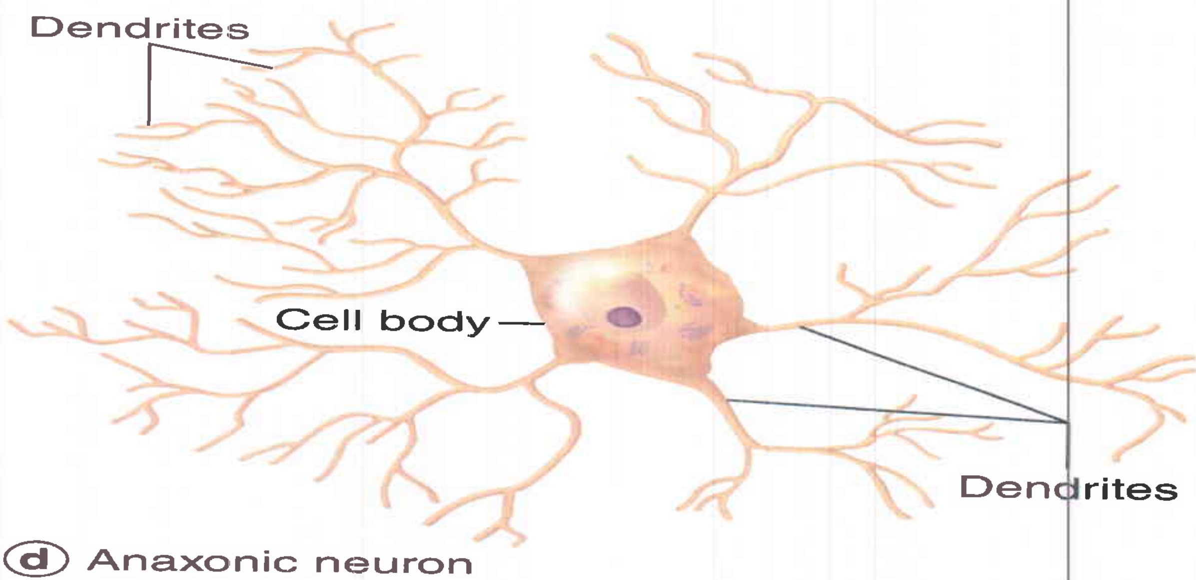

FIGURE 5.2

Figure 5.2 Structural classes of neurons:

Shown are the three main types of neurons, with short descriptions. (a) Most neurons, including all motor neurons and CNS interneurons, are multipolar. (b) Bipolar neurons include sensory neurons of the retina, olfactory mucosa, and inner ear. (c) All other sensory neurons are unipolar or pseudounipolar. (d) Anaxonic neurons of the CNS lack true axons and do not produce action potentials, but regulate local electrical changes of adjacent neurons.

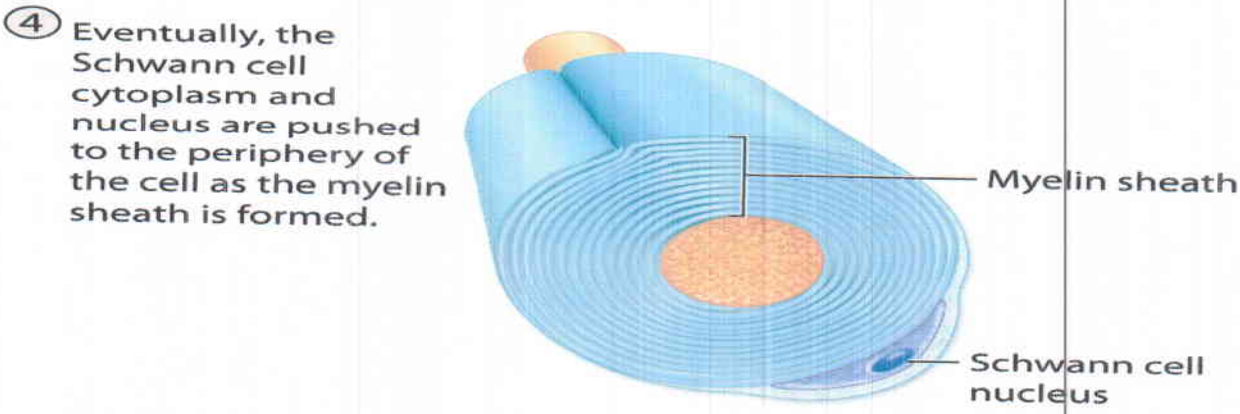

FIGURE 5.3

Figure 5.3 Myelination of large-diameter PNS axons:

A Schwann cell (neurolemmocyte) engulfs one portion along the length of a large-diameter axon. The Schwann cell membrane fuses around the axon and elongates as it becomes wrapped around the axon while the cell body moves around the axon many times. The Schwann cell membrane wrappings constitute the myelin sheath, with the Schwann cell body always on its outer surface. The myelin layers are very rich in lipid, and provide insulation and facilitate formation of action potentials along the axolemma.

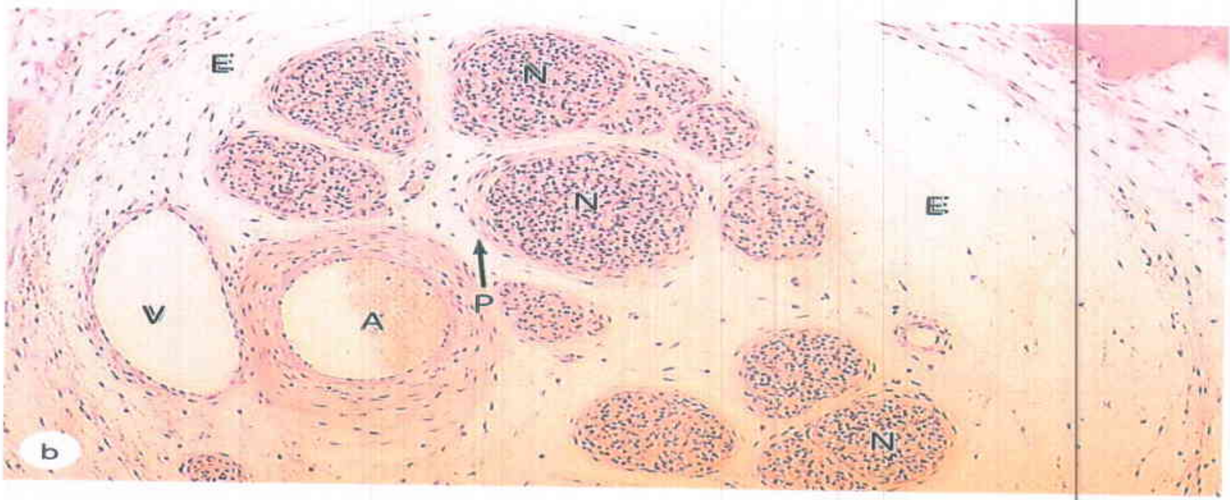

FIGURE 5.4

Figure 5.4 Peripheral nerve connective tissue: Epi-, peri-, and endoneurium:

(a) The diagram shows the relationship among these three connective tissue layers in large peripheral nerves. The epineurium (E) consists of a dense superficial region and a looser deep region that contains the larger blood vessels. (b) The micrograph shows a small vein (V) and artery (A) in the deep epineurium (E). Nerve fibers (N) are bundled in fascicles. Each fascicle is surrounded by the perineurium (P), consisting of a few layers of unusual squamous fibroblastic cells that are all joined at the peripheries by tight junctions. The resulting blood-nerve barrier helps regulate the microenvironment inside the fascicle. Axons and Schwann cells are in turn surrounded by a thin layer of endoneurium. X140. H&E.

(c) As shown here and in the diagram, septa (S) of connective tissue often extend from the perineurium into larger fascicles. The endoneurium (En) and lamellar nature of the perineurium (P) are also shown at this magnification, along with some adjacent epineurium (E). X200. PT.

(d) SEM of transverse sections of a large peripheral nerve showing several fascicles, each surrounded by perineurium and packed with endoneurium around the individual myelin sheaths. Each fascicle contains at least one capillary. Endothelial cells of these capillaries are tightly joined as part of the blood-nerve barrier and regulate the kinds of plasma substances released to the endoneurium. Larger blood vessels course through the deep epineurium that fills the space around the perineurium and fascicles. X450.