Cbcs 3rd sem major: paper 3026: unit 1

STRUCTURE, LOCATION , CLASSIFICATION AND FUNCTION OF EPITHELIAL TISSUE, CONNECTIVE TISSUE, MUSCULAR TISSUE AND NERVOUS TISSUE.

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Structure, location , classification and function of epithelial tissue

Epithelium is one of the four basic types of animal tissue, along with connective tissue, muscle tissue and nervous tissue. It is a thin, continuous, protective layer of cells.

Epithelial tissues line the outer surfaces of organs and blood vessels throughout the body, as well as the inner surfaces of cavities in many internal organs. An example is the epidermis, the outermost layer of the skin.

There are three principal shapes of epithelial cell: squamous, columnar, and cuboidal. These can be arranged in a single layer of cells as simple epithelium, either squamous, columnar, or cuboidal, or in layers of two or more cells deep as stratified (layered), or compound, either squamous, columnar or cuboidal.

In some tissues, a layer of columnar cells may appear to be stratified due to the placement of the nuclei. This sort of tissue is called a pseudostratified. All glands are made up of epithelial cells. Functions of epithelial cells include secretion, selective absorption, protection, transcellular transport, and sensing.

Epithelial layers contain no blood vessels, so they must receive nourishment via diffusion of substances from the underlying connective tissue, through the basement membrane. Cell junctions are well employed in epithelial tissues.

Structure

Epithelial tissue is scutoid shaped, tightly packed and form a continuous sheet. It has almost no intercellular spaces. All epithelia is usually separated from underlying tissues by an extracellular fibrous basement membrane.

The lining of the mouth, lung alveoli and kidney tubules are all made of epithelial tissue. The lining of the blood and lymphatic vessels are of a specialised form of epithelium called endothelium.

Location

Epithelium lines both the outside (skin) and the inside cavities and lumina of bodies. The outermost layer of human skin is composed of dead stratified squamous, keratinized epithelial cells.

Tissues that line the inside of the mouth, the esophagus, the vagina, and part of the rectum are composed of nonkeratinized stratified squamous epithelium.

Other surfaces that separate body cavities from the outside environment are lined by simple squamous, columnar, or pseudostratified epithelial cells. Other epithelial cells line the insides of the lungs, the gastrointestinal tract, the reproductive and urinary tracts, and make up the exocrine and endocrine glands.

The outer surface of the cornea is covered with fast-growing, easily regenerated epithelial cells. A specialised form of epithelium, endothelium, forms the inner lining of blood vessels and the heart, and is known as vascular endothelium, and lining lymphatic vessels as lymphatic endothelium.

Another type, mesothelium, forms the walls of the pericardium, pleurae, and peritoneum.[citation needed]

In arthropods, the integument, or external "skin", consists of a single layer of epithelial ectoderm from which arises the cuticle, an outer covering of chitin, the rigidity of which varies as per its chemical composition.

Basement membrane

Epithelial tissue rests on a basement membrane, which acts as a scaffolding on which epithelium can grow and regenerate after injuries.

Epithelial tissue has a nerve supply, but no blood supply and must be nourished by substances diffusing from the blood vessels in the underlying tissue.

The basement membrane acts as a selectively permeable membrane that determines which substances will be able to enter the epithelium.

Cell junctions

Cell junctions are especially abundant in epithelial tissues. They consist of protein complexes and provide contact between neighbouring cells, between a cell and the extracellular matrix, or they build up the paracellular barrier of epithelia and control the paracellular transport.

Cell junctions are the contact points between plasma membrane and tissue cells.

There are mainly 5 different types of cell junctions: tight junctions, adherens junctions, desmosomes, hemidesmosomes, and gap junctions.

Tight junctions are a pair of trans-membrane protein fused on outer plasma membrane. Adherens junctions are a plaque (protein layer on the inside plasma membrane) which attaches both cells' microfilaments.

Desmosomes attach to the microfilaments of cytoskeleton made up of keratin protein. Hemidesmosomes resemble desmosomes on a section. They are made up of the integrin (a transmembrane protein) instead of cadherin.

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They attach the epithelial cell to the basement membrane. Gap junctions connect the cytoplasm of two cells and are made up of proteins called connexins (six of which come together to make a connexion).

Development

Epithelial tissues are derived from all of the embryological germ layers:[citation needed

from ectoderm (e.g., the epidermis);

from endoderm (e.g., the lining of the gastrointestinal tract);

from mesoderm (e.g., the inner linings of body cavities).

However, it is important to note that pathologists do not consider endothelium and mesothelium (both derived from mesoderm) to be true epithelium. This is because such tissues present very different pathology. For that reason, pathologists label cancers in endothelium and mesothelium sarcomas, whereas true epithelial cancers are called carcinomas. Additionally, the filaments that support these mesoderm-derived tissues are very distinct. Outside of the field of pathology, it is generally accepted that the epithelium arises from all three germ layers

CLASSIFICATION

In general, epithelial tissues are classified by the number of their layers and by the shape and function of the cells.

The three principal shapes associated with epithelial cells are squamous, cuboidal, and columnar.

Squamous epithelium has cells that are wider than their height (flat and scale-like). This is found as the lining of the mouth, oesophagus, and including blood vessels and in the alveoli of the lungs.

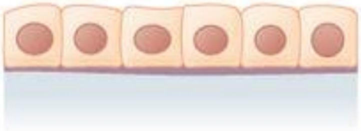
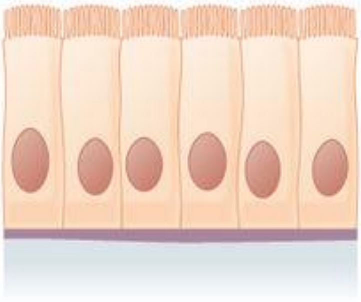
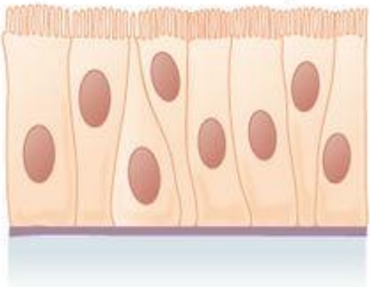
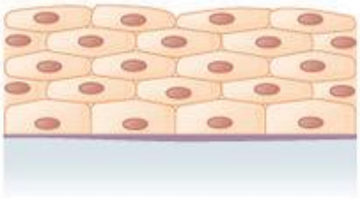
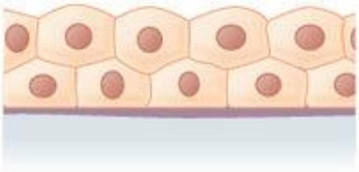
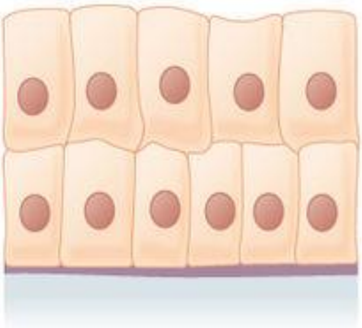
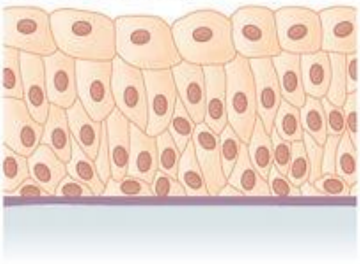
Cuboidal epithelium has cells whose height and width are approximately the same (cube shaped).

Columnar epithelium has cells taller than they are wide (column-shaped). Columnar epithelium can be further classified into ciliated columnar epithelium and glandular columnar epithelium

By layer, epithelium is classed as either simple epithelium, only one cell thick (unilayered), or stratified epithelium having two or more cells in thickness, or multi-layered – as stratified squamous epithelium, stratified cuboidal epithelium, and stratified columnar epithelium, and both types of layering can be made up of any of the cell shapes.

However, when taller simple columnar epithelial cells are viewed in cross section showing several nuclei appearing at different heights, they can be confused with stratified epithelia. This kind of epithelium is therefore described as pseudostratified columnar epithelium.

Transitional epithelium has cells that can change from squamous to cuboidal, depending on the amount of tension on the epithelium.

Cells	Location	Function
Simple squamous epithelium 	Air sacs of lungs and the lining of the heart, blood vessels, and lymphatic vessels	Allows materials to pass through by diffusion and filtration, and secretes lubricating substance
Simple cuboidal epithelium 	In ducts and secretory portions of small glands and in kidney tubules	Secretes and absorbs
Simple columnar epithelium 	Ciliated tissues are in bronchi, uterine tubes, and uterus; smooth (nonciliated tissues) are in the digestive tract, bladder	Absorbs; it also secretes mucous and enzymes
Pseudostratified columnar epithelium 	Ciliated tissue lines the trachea and much of the upper respiratory tract	Secretes mucus; ciliated tissue moves mucus
Stratified squamous epithelium 	Lines the esophagus, mouth, and vagina	Protects against abrasion
Stratified cuboidal epithelium 	Sweat glands, salivary glands, and the mammary glands	Protective tissue
Stratified columnar epithelium 	The male urethra and the ducts of some glands	Secretes and protects
Transitional epithelium 	Lines the bladder, uretha, and the ureters	Allows the urinary organs to expand and stretch

Simple epithelium

Simple epithelium is a single layer of cells with every cell in direct contact with the basement membrane that separates it from the underlying connective tissue. In general, it is found where absorption and filtration occur. The thinness of the epithelial barrier facilitates these processes.

In general, simple epithelial tissues are classified by the shape of their cells. The four major classes of simple epithelium are

(1) simple squamous,
(2) simple cuboidal,
(3) simple columnar, and
(4) pseudostratified

1) Simple squamous: Squamous epithelial cells appear scale-like, flattened, or rounded (e.g., walls of capillaries, linings of the pericardial, pleural, and peritoneal cavities, linings of the alveoli of the lungs).

(2) Simple cuboidal: These cells may have secretory, absorptive, or excretory functions. Examples include small collecting ducts of the kidney, pancreas, and salivary gland.

(3) Simple columnar: Cells can be secretory, absorptive, or excretory. Simple columnar epithelium can be ciliated or non-ciliated; ciliated columnar is found in the female reproductive tract and uterus.

Non-ciliated epithelium can also possess microvilli. Some tissues contain goblet cells and are referred to as simple glandular columnar epithelium. These secrete mucus and are found in the stomach, colon, and rectum.

(4) Pseudostratified columnar epithelium: These can be ciliated or non-ciliated. The ciliated type is also called respiratory epithelium since it is almost exclusively confined to the larger respiratory airways of the nasal cavity, trachea, and bronchi.

Stratified epithelium

Stratified epithelium differs from simple epithelium in that it is multilayered.

It is therefore found where body linings have to withstand mechanical or chemical insult such that layers can be abraded and lost without exposing subepithelial layers.

Cells flatten as the layers become more apical, though in their most basal layers, the cells can be squamous, cuboidal, or columnar.

Stratified epithelia (of columnar, cuboidal, or squamous type) can have the following specializations

Keratinized

In this particular case, the most apical layers (exterior) of cells are dead and lose their nucleus and cytoplasm, instead contain a tough, resistant protein called keratin. This specialization makes the epithelium somewhat water-resistant, so is found in the mammalian skin. The lining of the esophagus is an example of a non-keratinized or "moist" stratified epithelium.

Parakeratinized

In this case, the most apical layers of cells are filled with keratin, but they still retain their nuclei. These nuclei are pyknotic, meaning that they are highly condensed. Parakeratinized epithelium is sometimes found in the oral mucosa and in the upper regions of the esophagus

Transitional

Transitional epithelia are found in tissues that stretch, and it can appear to be stratified cuboidal when the tissue is relaxed, or stratified squamous when the organ is distended and the tissue stretches. It is sometimes called urothelium since it is almost exclusively found in the bladder, ureters and urethra

Cell types

Squamous Squamous cells have the appearance of thin, flat plates that can look polygonal when viewed from above. Their name comes from squāma, Latin for "scale" – as on fish or snake skin. The cells fit closely together in tissues, providing a smooth, low-friction surface over which fluids can move easily.

The shape of the nucleus usually corresponds to the cell form and helps to identify the type of epithelium. Squamous cells tend to have horizontally flattened, nearly oval-shaped nuclei because of the thin, flattened form of the cell.

Squamous epithelium is found lining surfaces such as skin or alveoli in the lung, enabling simple passive diffusion as also found in the alveolar epithelium in the lungs. Specialized squamous epithelium also forms the lining of cavities such as in blood vessels (as endothelium), in the pericardium (as mesothelium), and in other body cavities.

Cuboidal Cuboidal epithelial cells have a cube-like shape and appear square in cross-section. The cell nucleus is large, spherical and is in the center of the cell.

Cuboidal epithelium is commonly found in secretive tissue such as the exocrine glands, or in absorptive tissue such as the pancreas, the lining of the kidney tubules as well as in the ducts of the glands.

The germinal epithelium that covers the female ovary, and the germinal epithelium that lines the walls of the seminferous tubules in the testes are also of the cuboidal type.

Cuboidal cells provide protection and may be active in pumping material in or out of the lumen, or passive depending on their location and specialisation. Simple cuboidal epithelium commonly differentiates to form the secretory and duct portions of glands.

Stratified cuboidal epithelium protects areas such as the ducts of sweat glands, mammary glands, and salivary glands

Columnar

Columnar epithelial cells are elongated and column-shaped and have a height of at least four times their width. Their nuclei are elongated and are usually located near the base of the cells. Columnar epithelium forms the lining of the stomach and intestines.

The cells here may possess microvilli for maximizing the surface area for absorption, and these microvilli may form a brush border. Other cells may be ciliated to move mucus in the function of mucociliary clearance.

Other ciliated cells are found in the fallopian tubes, the uterus and central canal of the spinal cord. Some columnar cells are specialized for sensory reception

such as in the nose, ears and the taste buds. Hair cells in the inner ears have stereocilia which are similar to microvilli.

Goblet cells are modified columnar cells and are found between the columnar epithelial cells of the duodenum. They secrete mucus, which acts as a lubricant. Single-layered non-ciliated columnar epithelium tends to indicate an absorptive function.

Stratified columnar epithelium is rare but is found in lobar ducts in the salivary glands, the eye, the pharynx, and sex organs. This consists of a layer of cells resting on at least one other layer of epithelial cells, which can be squamous, cuboidal, or columnar.

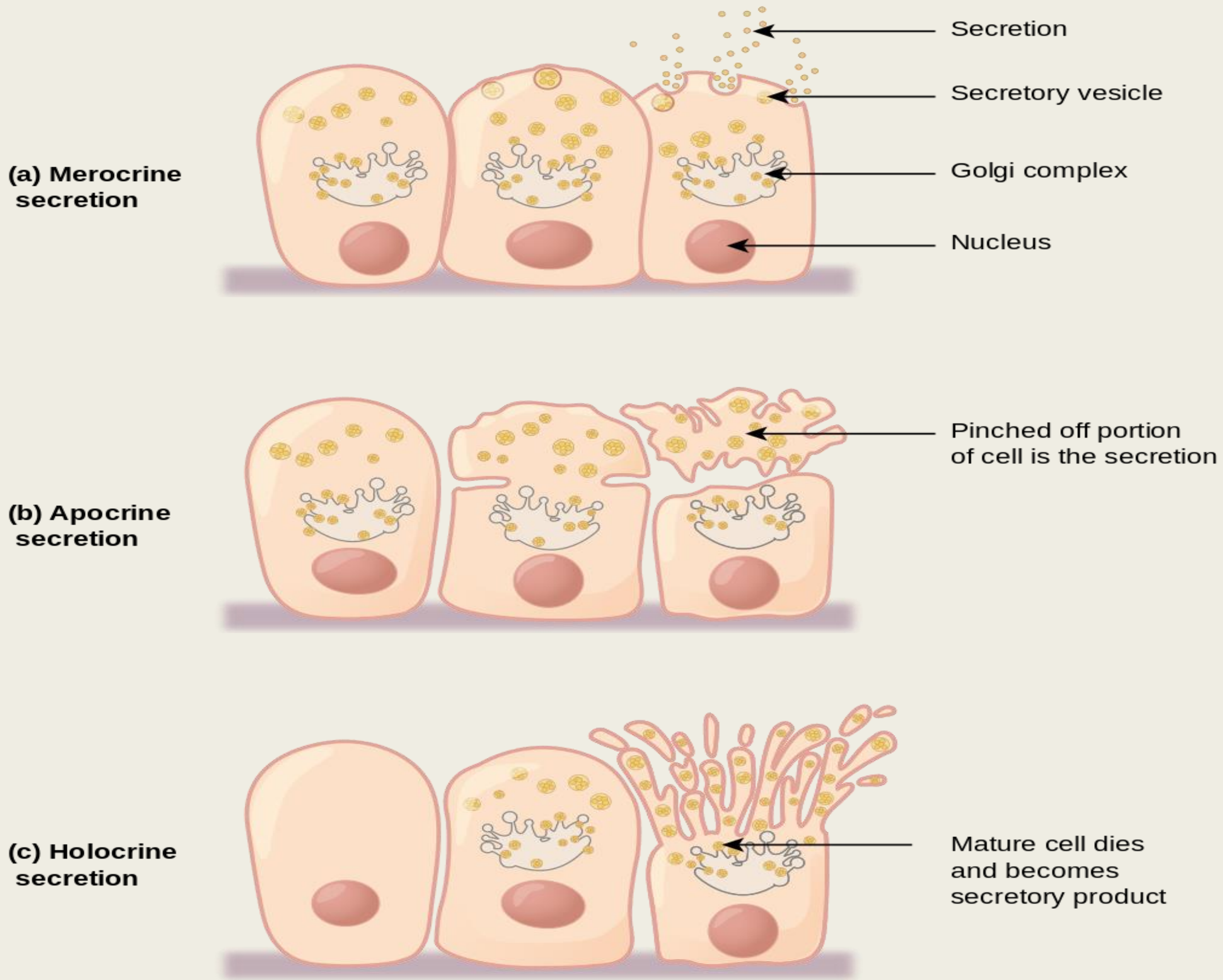
Pseudostratified These are simple columnar epithelial cells whose nuclei appear at different heights, giving the misleading (hence "pseudo") impression that the epithelium is stratified when the cells are viewed in cross section. Ciliated pseudostratified epithelial cells have cilia.

Cilia are capable of energy-dependent pulsatile beating in a certain direction through interaction of cytoskeletal microtubules and connecting structural proteins and enzymes. In the respiratory tract, the wafting effect produced causes mucus secreted locally by the goblet cells (to lubricate and to trap pathogens and particles) to flow in that direction (typically out of the body).

Ciliated epithelium is found in the airways (nose, bronchi), but is also found in the uterus and Fallopian tubes, where the cilia propel the ovum to the uterus

Functions

Forms of secretion in glandular tissue



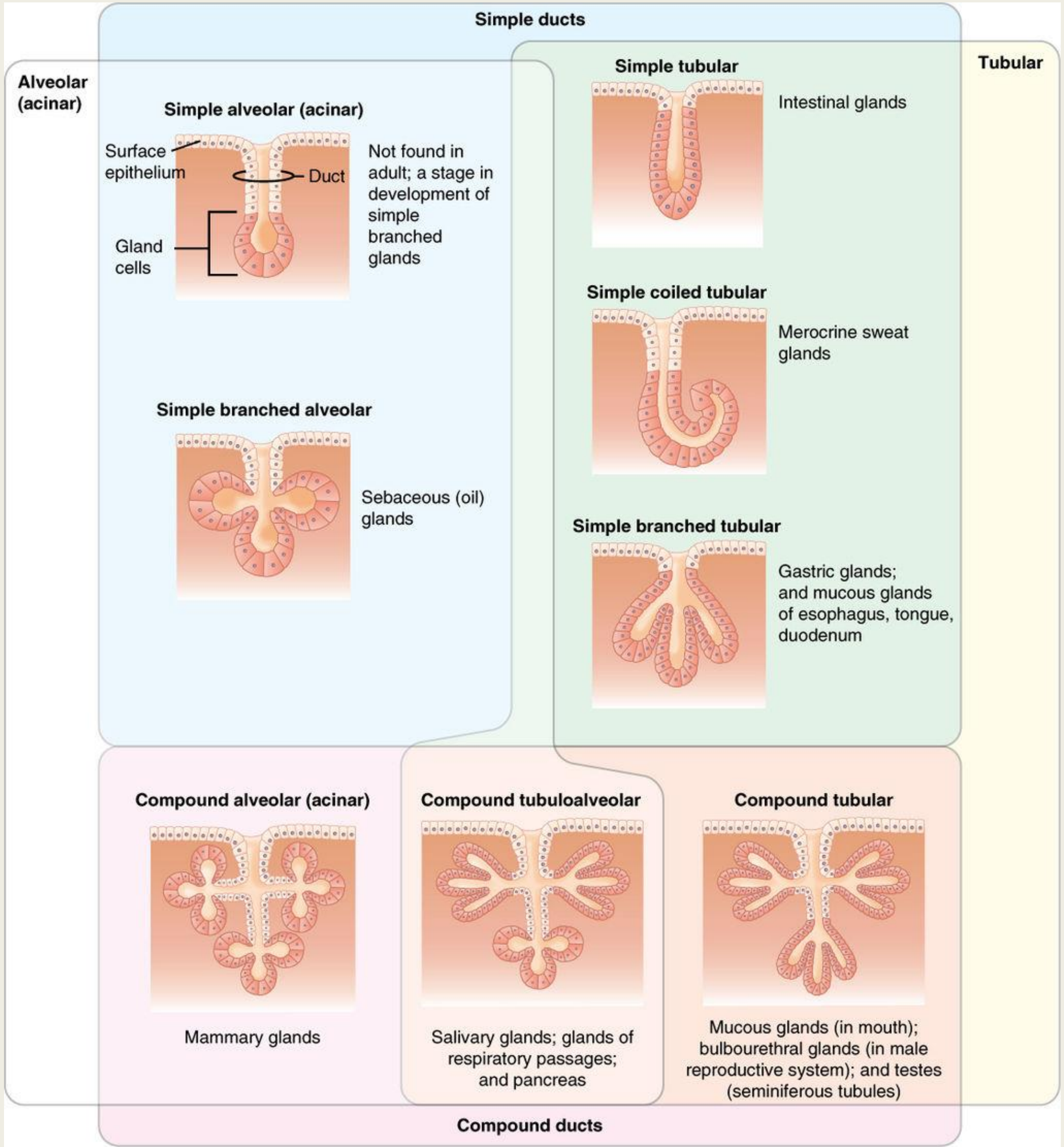
Epithelial tissues have as their primary functions:

to protect the tissues that lie beneath from radiation, desiccation, toxins, invasion by pathogens, and physical trauma.

The regulation and exchange of chemicals between the underlying tissues and a body cavitythe secretion of hormones into the circulatory system, as well as the secretion of sweat, mucus, enzymes, and other products that are delivered by ducts

to provide sensation

Absorb water and digested food in the lining of digestive canal.



Different characteristics of glands of the body

Glandular tissue

Glandular tissue is the type of epithelium that forms the glands from the infolding of epithelium and subsequent growth in the underlying connective tissue. There are two major classifications of glands: endocrine glands and exocrine glands:

Endocrine glands secrete their product into the extracellular space where it is rapidly taken up by the circulatory system.

Exocrine glands secrete their products into a duct that then delivers the product to the lumen of an organ or onto the free surface of the epithelium.

Sensing the extracellular environment

"**Some epithelial cells are ciliated, especially in respiratory epithelium, and they commonly exist as a sheet of polarised cells forming a tube or tubule with cilia projecting into the lumen.**

" Primary cilia on epithelial cells provide chemosensation, thermoception, and mechanosensation of the extracellular environment by playing "a sensory role mediating specific signalling cues, including soluble factors in the external cell environment, a secretory role in which a soluble protein is released to have an effect downstream of the fluid flow, and mediation of fluid flow if the cilia are motile

Clinical significance

Epithelial cell infected with Chlamydia pneumoniae

The slide shows at
(1) an epithelial cell infected by Chlamydia pneumoniae; their inclusion bodies shown at (3); an uninfected cell shown at (2) and (4) showing the difference between an infected cell nucleus and an uninfected cell nucleus. Epithelium grown in culture can be identified by examining its morphological characteristics.

Epithelial cells tend to cluster together, and have a "characteristic tight pavement-like appearance". But this is not always the case, such as when the cells are derived from a tumor. In these cases, it is often necessary to use certain biochemical markers to make a positive identification. The intermediate filament proteins in the cytokeratin group are almost exclusively found in epithelial cells, so they are often used for this purpose. Cancers originating from the epithelium are classified as carcinomas. In contrast, sarcomas develop in connective tissue.

Structure, location , classification and function of , connective tissue

INTRODUCTION

Most widespread and abundant type of tissue in the human body.

Major constituent is extracellular matrix, composed of fibres, ground substance & tissue fluid.

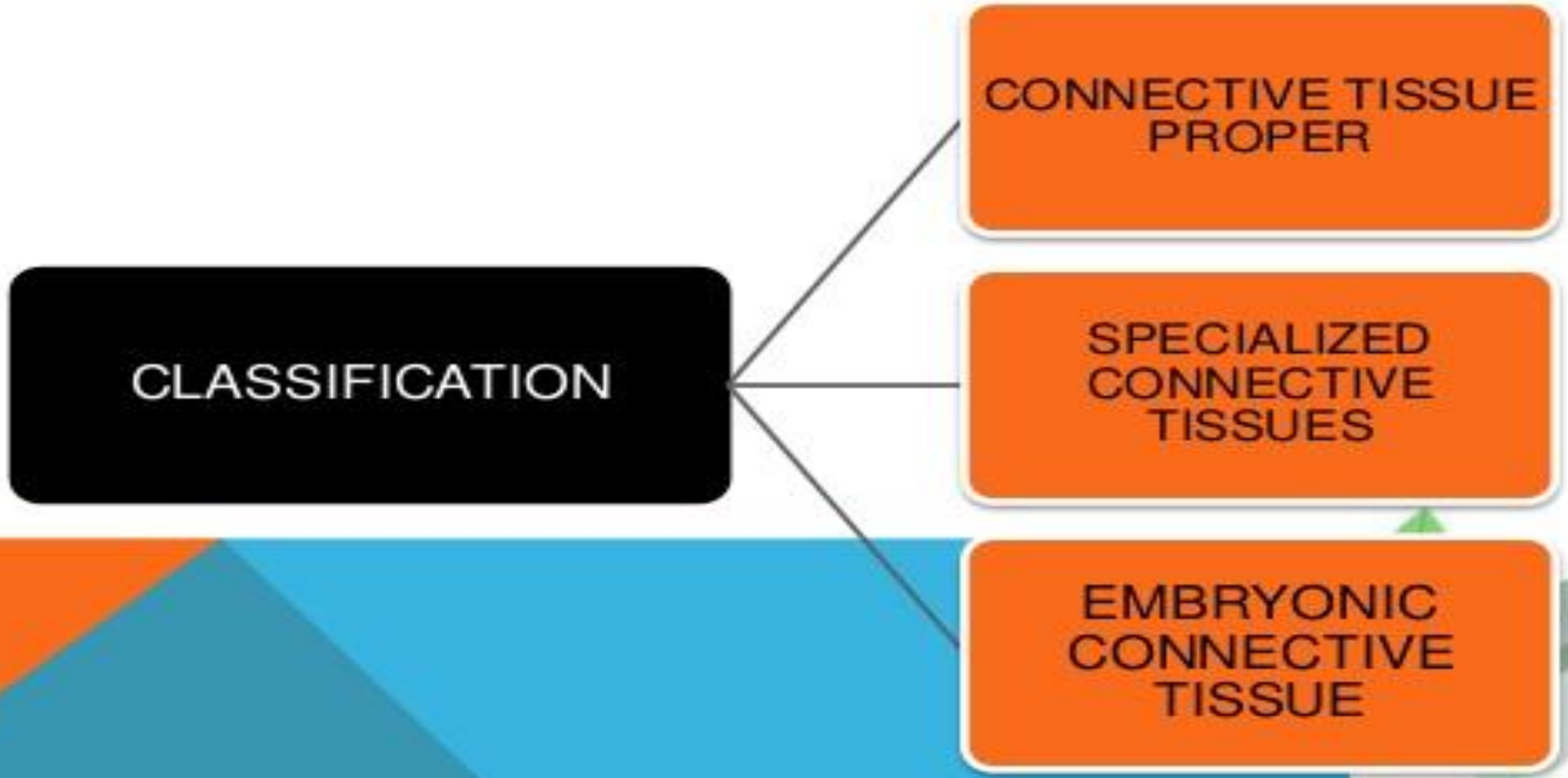
Embedded within the extracellular matrix are the connective tissue cells.

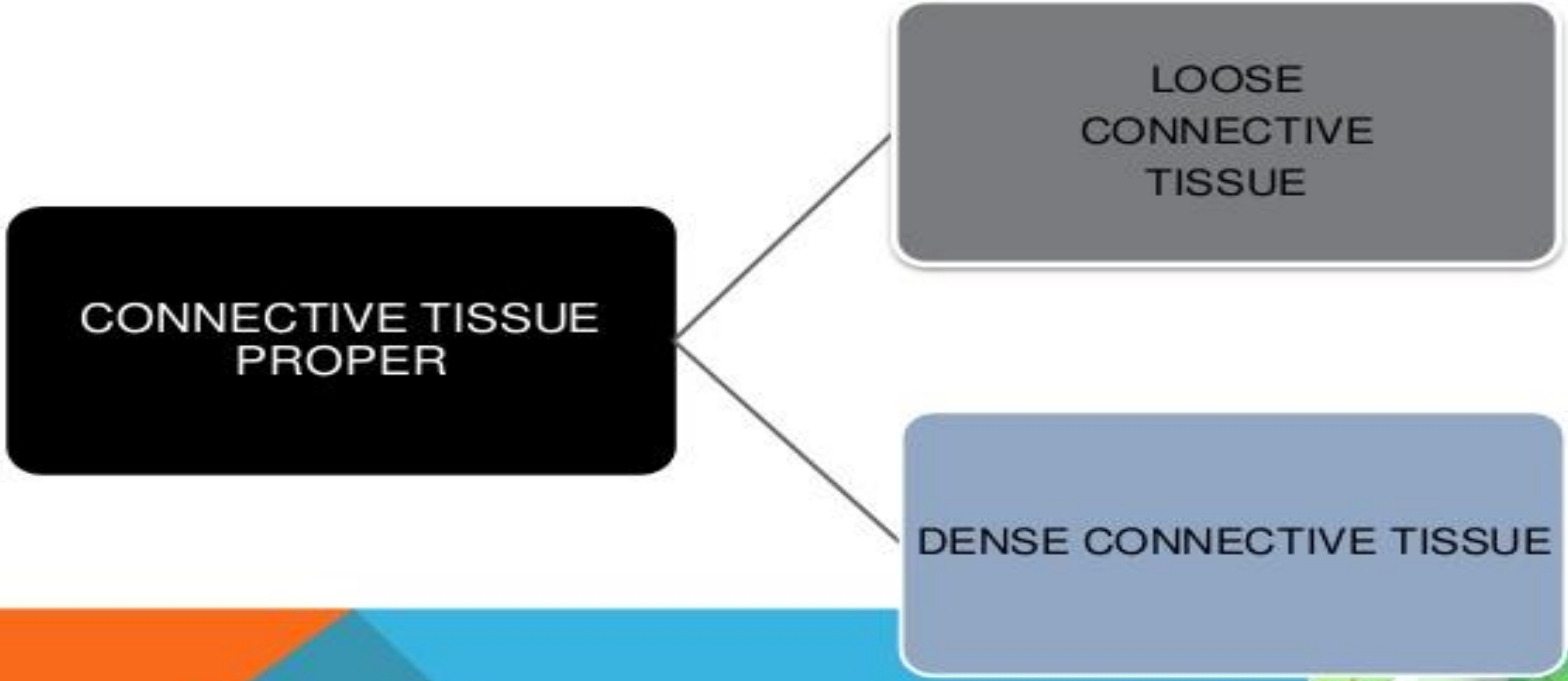
Structurally, connective tissue can be divided into 3 classes: cells, fibres & ground substance.

Forms a vast and continuous compartment throughout the body bounded by basal lamina of epithelia and by basal lamina of muscle, nerves and vascular endothelium.

CLASSIFICATION

Classification is based on the composition and organization of cellular and extracellular components and on special functions.




CONNECTIVE TISSUE PROPER
LOOSE CONNECTIVE TISSUE
DENSE CONNECTIVE TISSUE

SPECIALISED CONNECTIVE TISSUE

- ADIPOSE CONNECTIVE TISSUE
- RETICULAR CONNECTIVE TISSUE
- ELASTIC CONNECTIVE TISSUE

EMBRYONAL CONNECTIVE TISSUE

- MESENCHYMAL CONNECTIVE TISSUE
- MUCUOS CONNECTIVE TISSUE

FUNCTIONS

Forms capsules that surround the organs of the body & the internal architecture

Makes up tendons, ligaments & areolar tissue that fills the spaces between the tissues.

Bone, cartilage & adipose tissue are specialized types of connective tissue that support the soft tissues of the body & store fat.

Role in defending the organism due to the phagocytic & immuno-competent cells

Phagocytic cells engulf inert particles & micro-organisms that enter the body.

Specific proteins called antibodies are produced by plasma cells in the connective tissue.

Provide a physical barrier

Plays role in cell nutrition.

Serves as a medium through which nutrients & metabolic wastes are exchanged between cells & their blood supply.

CONNECTIVE TISSUE COMPONENTS

All connective tissue possess three basic components :

Ground Substance

Fibers

Cells

GROUND SUBSTANCE

A complex mixture of glycoproteins & proteoglycans

Participate in binding cells to the fibers of connective tissues

Colorless & transparent.

Fills the space between cells & fibers

Viscous

Acts as both a lubricant & a barrier to the penetration of foreign particles.

Granular in appearance

Consistency varies from fluid to gel

GLYCOPROTEINS

Glycoproteins are proteins that contain oligosaccharide chains (glycans) covalently attached to polypeptide side-chains. The carbohydrate is attached to the protein in a cotranslational or posttranslational modification.

The major types of adhesive glycoproteins are **fibronectin**, **laminin**, and **entactin**.

VARIOUS GLYCOPROTEINS/ PRESENT ARE

FIBRONECTIN:

- Is a glycoprotein synthesized by fibroblasts and some epithelial cells.
- Binds with collagen
- Connects collagen fibers to cells of connective tissue.

FIBRILLIN:

- Forms elastic fibers in CT.
- Responsible for adhesion of different extracellular components to one another.

LAMININ:

- Present in basement membrane.
- Laminin helps in adhesion of epithelial cells to basal lamina

ENTACTIN:

Adhesive glycoprotein

Seen in embryonic tissue.

Play a role in cell migration .

CHONDRONECTIN & OSTEOPONTIN:

Chondronectin and osteonectin are similar to fibronectin. *Chondronectin* has binding sites for type II collagen, chondroitin sulfates, hyaluronic acid, and integrins of chondroblasts and chondrocytes. *Osteonectin* possesses domains for type I collagen, proteoglycans, and integrins of osteoblasts and osteocytes.

Type	Tissue Distribution	Functions
Fibronectin	Widely distributed in extracellular structures; cell surface, especially fibroblasts; basal laminae; external laminae of muscle	Cell adhesion (to integrins), collagen-binding (I, II, IV), heparan sulfate- and hyaluronic acid-binding
Laminin	Basal laminae, external laminae of muscle	Binds to epithelial and muscle cells, to type IV collagen, and to heparan sulfate
Entactin (nidogen)	Basal laminae	Binds to laminin and type IV collagen
Thrombospondin	Blood plasma, platelets, fibroblasts, endothelium, smooth muscle cells	Secreted by platelets during blood clotting, binds to fibrinogen, etc.; in muscle, skin and blood vessels, binds to collagen, heparin and fibronectin
Chondronectin	Cartilage	Chondrocyte-binding, collagen (type II)-binding, proteoglycan-binding
Osteopontin	Bone	Promotes cell adhesion to extracellular matrix, including osteoclasts to bone

GLYCOSAMINOGLYCANS/ MUCOPOLYSACCHARIDES

-Are linear polysaccharides formed by repeating disaccharide units

-Composed of a uronic acid and a hexosamine.

-Hexosamine can be glucosamine or galactosamine

-Uronic acid can be glucuronic acid or iduronic acid.

-Linear chains are bound covalently to a protein core

GAGs are long, inflexible, unbranched polysaccharides composed of chains of repeating disaccharide units.

In cartilage, the proteoglycan molecules are bound to a hyaluronic side chain

Because of the abundance of hydroxyl, carboxyl & sulfate groups, the proteoglycans are hydrophilic & act as polyanions.

Type	Tissue Distribution	Functions
Hyaluronic acid	Widely distributed, found in variable amounts in all tissues and fluids in adults; loose connective tissue; skin; umbilical cord; vitreous; synovial fluid; cartilage	Resists compressive forces in tissues and joints; space filler during embryonic development; facilitates cell migration during tissue morphogenesis and repair
Chondroitin sulfate	Hyaline and elastic cartilage, bone	Mechanical support; forms large aggregations with hyaluronic acid
Dermatan sulfate	Dermis, tendons, ligaments, heart valves, organ capsules, sclera, fibrocartilage, arteries (adventitia), nerves (epineurium)	Binds to type I collagen fibrils
Keratan sulfate	Bone, cartilage, cornea	Mechanical support
Heparan sulfate	Fibroblast and epithelial cell surface, basal and external laminae	Cell adhesion; binds FGF; structural and filtering function in basal laminae

PROTEOGLYCANS

- When sulfated GAG's form covalent bonds with a protein core , they form a family of macro molecules known as proteoglycans.

- Look like a bottle brush, with the protein core resembling the wire stem and the various sulfated GAGs projecting from its surface in three dimensional space, as do the bristles of the brush.
- Proteoglycans have numerous functions. By occupying a large volume, they resist compression and retard the rapid movement of microorganisms and metastatic cells.
- In addition, in association with the basal lamina, they form molecular filters of varying pore sizes and charge distributions that selectively screen and retard macromolecules as they pass through.

- Proteoglycans also possess binding sites for certain signaling molecules, such as various growth factors. By binding these signaling molecules, proteoglycans can either impede their function by preventing the molecules from reaching their destinations or enhance their function by concentrating them in a specific location.

FUNCTIONS OF GROUND SUBSTANCE

Transport of metabolites to and from the vascular channels.

Maintenance of electrolyte balance.

Fills up spaces between cells and fibers of connective tissue.

Acts as a barrier to penetration of foreign particles into tissues.

TISSUE FLUID

In CT in addition to the ground substance there is a very small quantity of fluid called " TISSUE FLUID"

Its is the extracellular fluid in CT as well as in other tissues.

Formed by exchange with blood plasma across endothelial layers

Is approx. equal to blood plasma

Is a solution that bathes and surrounds the cells of multicellular animals. It is the main component of the extracellular fluid, which also includes plasma and transcellular fluid.

Provides a means of delivering materials to the cells, intercellular communication, as well as removal of metabolic waste.

Water in intercellular substances of CT comes from blood, passing through capillary walls into intercellular regions of tissue. The capillary wall is slightly permeable to macromolecules but permits the passage of water and small molecules, including low molecular weight proteins..

CONNECTIVE TISSUE FIBRES

Connective tissue fibers are long, slender protein polymers

COLLAGEN FIBRES

RETICULAR FIBRES

ELASTIC FIBRES

COLLAGEN FIBRES

Most abundant protein in mammals

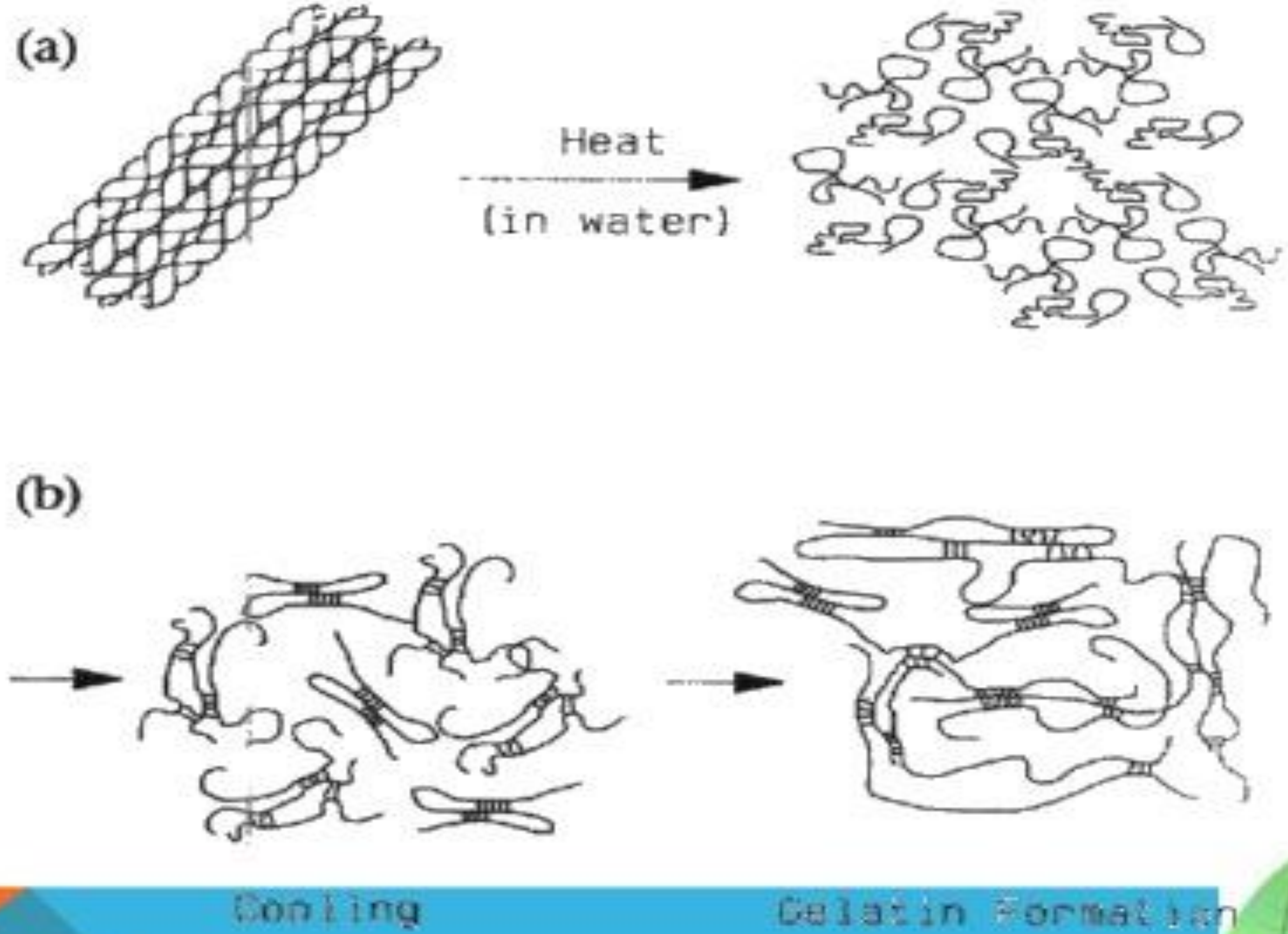
Accounts for 25-30% total protein content.

Main fibrous component of skin, bone, tendon, cartilage and teeth.

Comprises about 90% of the organic matrix of the bone.

Word ‘collagen’ Kolla comes from Greek meaning ‘glue producer’.

When collagen is heated in water, it gradually breaks down to produce soluble derived protein i.e. gelatin or animal glue.


(a)
Heat
(in water)
(b)
Cooling
Gelatin Formation

Fibers made up of collagen have a high tensile strength.

An important structural component in tissues such as the periodontal ligament and muscle tendons in which the mechanical forces need to be transmitted without loss.

STRUCTURE

Collagen subunit or **tropocollagen** is a rod about 300 nm long and 1.5nm in diameter.

Composed of 3 polypeptide alpha chains coiled around each other to form the **tripe helix configuration,** stabilized by numerous H_2 bonds.

Individual polypeptide chains contain app. 1000 amino acid residue.

α chains are left handed helices that wrap around each other into a right handed rope like triple helical rod.

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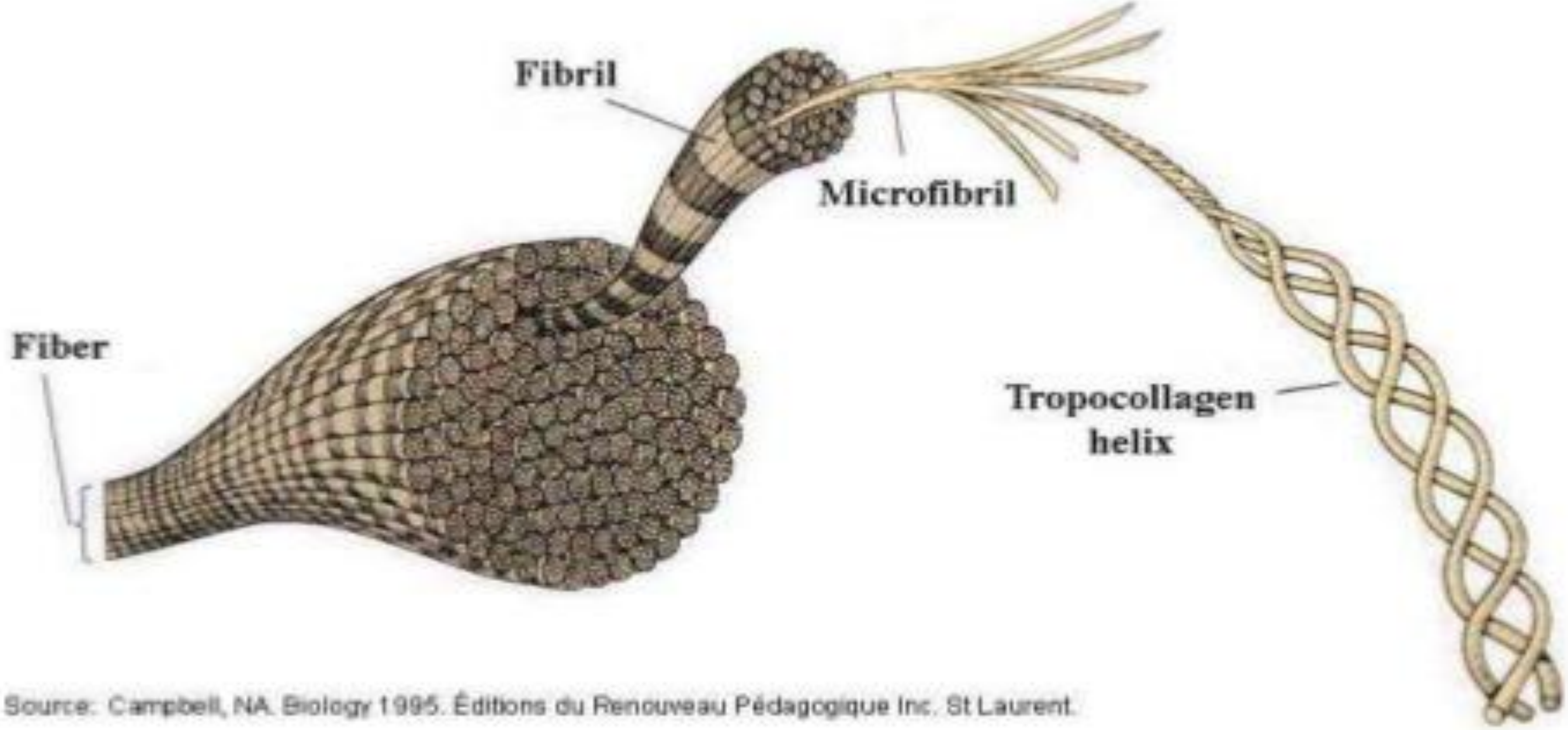


Source: Campbell, NA. Biology 1995. Éditions du Renouveau Pédagogique Inc. St Laurent.

BIOSYNTHESIS OF COLLAGEN

- **Involved in tissue differentiation, growth and remodeling.**
- **Young tissue has higher rate of collagen synthesis.**
- **As the tissues matures in adults, synthesis continues as a part of normal tissue turnover.**
- **Highest rate of collagen turnover are observed in weight bearing bones, lungs and periodontal tissues.**
- **Collagen synthesis is elevated under conditions like remodeling and replacement of tissues and during tissue repair.**
- **Elevated rates in pathological conditions such as fibrosis in lungs and liver.**

COLLAGEN BIOSYNTHESIS

Synthesis of pro alpa chains

↓

Hydroxylation of proline and lysine

↓

Glycosylation of hydroxylysine in ribosomes

↓

Assembly of pro alpha chains into triple helix

Packaging of the procollagen by the golgi into secretory vesicles

⇩

Transport of pro collagen containing vesicles along cytoplasmic microtubules to cell surface

⇩

Cleavage of registration peptides to form tropocollagen molecules

⇩

Assembly of tropocollagen molecules into micro fibrils

⇩

Side by Side crosslinking of collagen fibrils to form collagen filres

BONE COLLAGEN

Contains type I collagen predominantly .

Insoluble in neutral salts.

Slightly soluble in dilute acid solutions.

High degree of hydroxylation of lysine imparts the insolubility even after decalcification.

CLINICAL SIGNIFICANCE

Collagen are the most abundant proteins. alteration in collagen structure resulting from abnormal genes or abnormal processing result in numerous diseases as-

Osteogenesis imperfecta

Scurvy

Ehler-Danler syndrome

Alport syndrome

Epidermolysis bullosa

Stickler syndrome

Lupus erythematosis

Scleroderma

RETICULAR FIBRES

Extremely thin, with a diameter between 0.5-2μm

Form an extensive network

Not visible in hematoxylin and eosin (H&E) preparations

Stained black by impregnation with silver salts.

PAS+ve.

Contain 6-12% hexose.

Composed mainly of collagen type 3 in association with other types of collagen, glycoproteins & proteoglycans.

Formed by loosely packed, thin fibrils bound together by abundant small interfibrillar bridges composed of glycoproteins & proteoglycans.

Abundant in smooth muscle, endoneurium & the framework of hematopoietic organs

Constitute a network around the cells of parenchymal organs.

Small diameter & loose disposition of reticular fibers create a flexible network in organs that are subjected to changes in form or volume, such as arteries, spleen, liver, uterus & intestinal muscle layers.

ELASTIC FIBRE SYSTEM

Composed of 3 types of fibers: oxytalan, elaunin, elastic.

Structure of the elastic fiber system develop through 3 successive stages:’

First Stage: consists of a bundle of 10nm microfibrils composed of various glycoproteins, including one with a large molecule called fibrillin. These oxytalan fibers can be found in the zonule fibers of the eye & dermis.

Second stage: an irregular deposition of the protein elastin appears between the oxytalan fibers, forming the elaunin fibers. These structures are found around sweat glands & dermis.

Third stage: elastin gradually accumulates until it occupies the center of the fiber bundles, which are further surrounded by a thin sheath of microfibrils. These are elastic fibers, the most numerous component of the elastic fiber system.

Oxytalan fibers are highly resistant to pulling forces

Elastic fibers, which are rich in protein elastin, stretch easily in response to tension.

Elastic fiber system constitutes a family of fibers whose variable functional characteristics are adapted to local tissue requirements.

CELLS

Connective tissue cells are:

Undifferentiated Mesenchymal cells

Fibroblasts

Adipose (fat cells)

Macrophages

Leukocytes

Mast cells

Plasma cells

UNDIFFERENTIATED MESENCHYMAL CELLS

Stellate in shape

Large, pale staining nuclei occupy the centre of the cell.

Cytoplasm is hardly distinguishable.

Processes of cell contact those of their neighboring cells giving the impression of a network.

Found most commonly in mesenchyme of embryos.

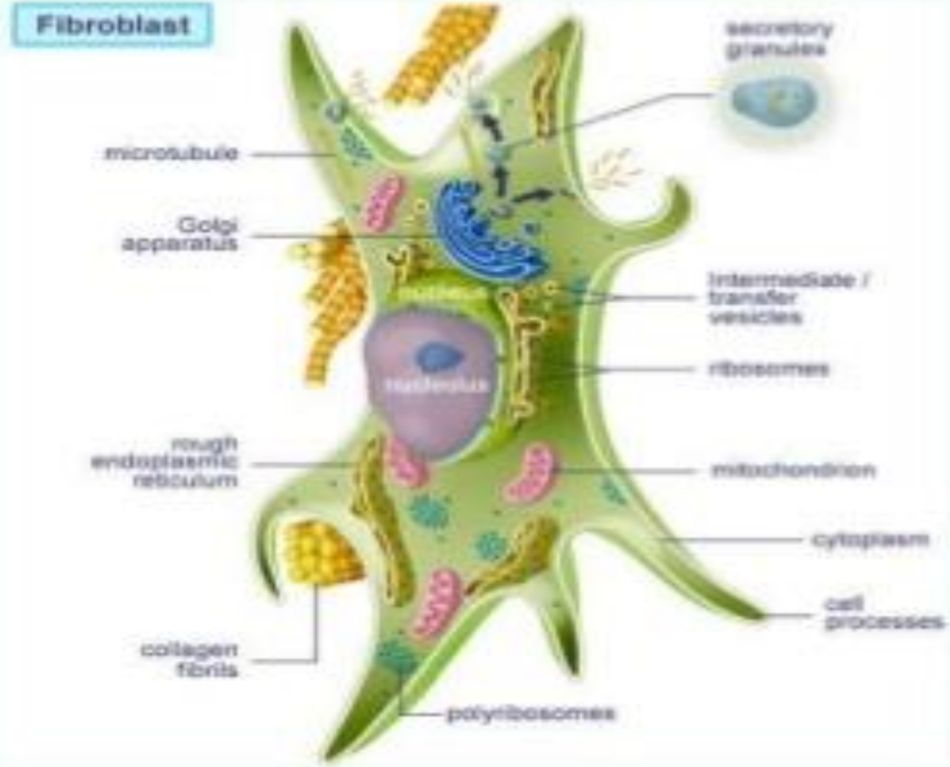
In mature tissue, these cells are scarce and are found principally near the capillaries where they function in the repair processes when tissue is injured.

FIBROBLASTS

Most common cells

Are ovoid or spindle shaped and can be large or small in size depending on their stage of cellular activity.

Have pale staining cytoplasm & contain well developed RER & rich golgi complexes.



Fibrocyte:

Found scattered among the fibres it has already synthesized.

Smaller than fibroblast.

Spindle shaped and has fewer processes.

Presents with a smaller and darker elongated nucleus

Acidophilic cytoplasm

Less developed granular endoplasmic reticulum and golgi apparatus.

The myofibroblast, a cell with features of both fibroblasts & smooth muscle, is also observed during wound healing. These cells have morphologic characteristics of fibroblasts but contain increased amounts of actin microfilaments & myosin

Function of fibroblasts are the production of ground substance and fibrils and fibril maintenance.

Fibroblasts secrete procolllagen molecules into the intercellular matrix and their polymerization into microfibrils takes place outside the cytoplasm.

Extracellularly and even on the surface membrane of fibroblast, enzyme action effects the conversion of procollagen to tropocollagen and finally into collagen fibrils.

ADIPOSE (FAT CELLS)

Adipose cells are connective tissue cells that have become specialized for storage of neutral fats.

They gradually accumulate cytoplasmic fat, which results in a significant flattening of the nucleus in the periphery of the cell.

Found throughout body, particularly in Loose CT

Function is to store energy in form of triglycerides & to synthesize hormones such as leptin.

MACROPHAGES: THE MONONUCLEAR PHAGOCYTE SYSTEM

- Also called as histocytes, are highly phagocytic cells that are derived frpm blood monocytes.
- Term macrophage means **BIG EATER**.
- Stellate or spindle shaped cells
- Nuclei are centrally located and oval, small in size
- Zoologist and anatomist **Metchnikoff** elaborated the concept of Phagocytosis.
- Difficult to identify.

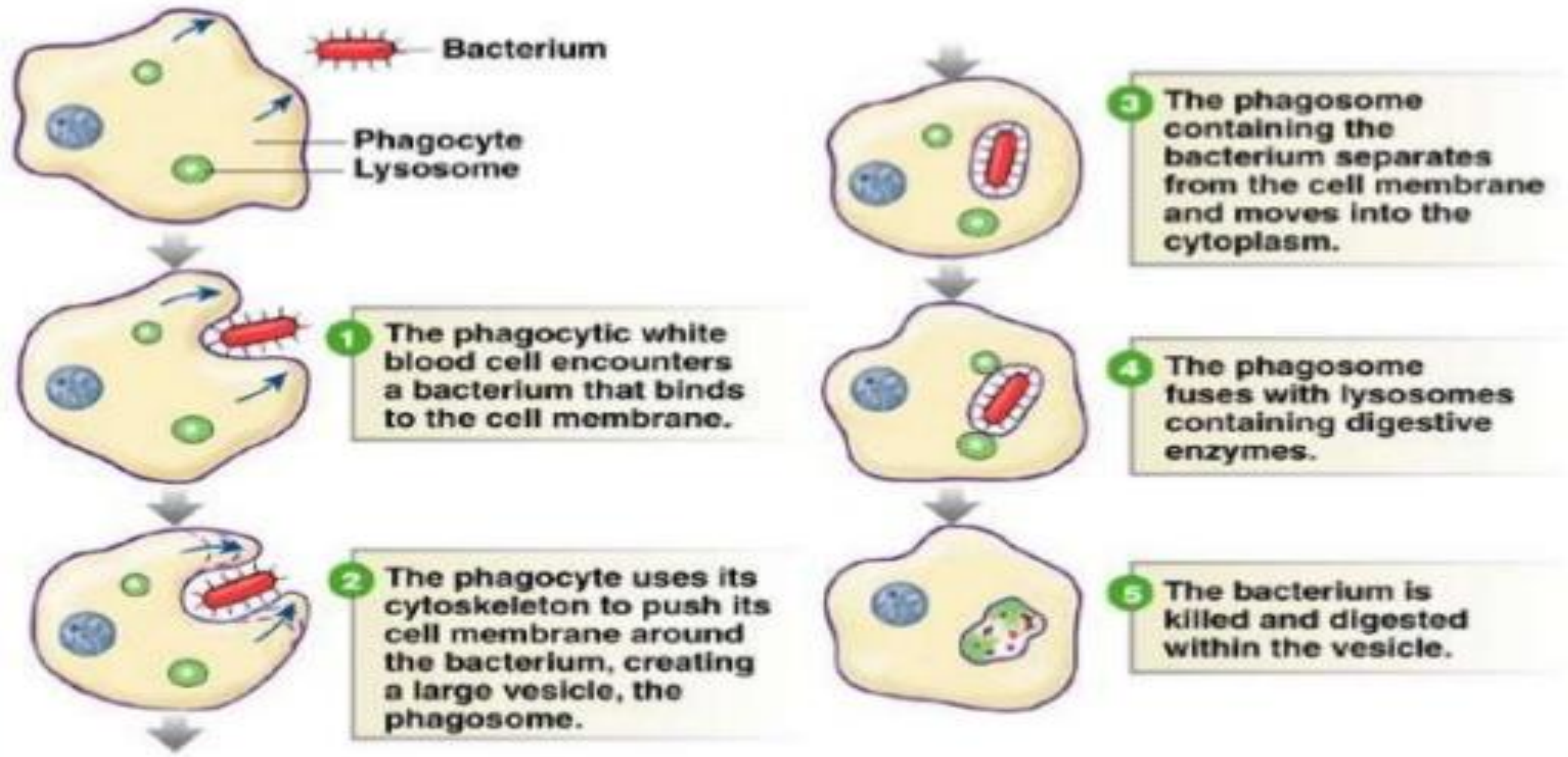

Bacterium
Phagocyte
Lysosome
1 The phagocytic white blood cell encounters a bacterium that binds to the cell membrane.
2 The phagocyte uses its cytoskeleton to push its cell membrane around the bacterium, creating a large vesicle, the phagosome.
3 The phagosome containing the bacterium separates from the cell membrane and moves into the cytoplasm.
4 The phagosome fuses with lysosomes containing digestive enzymes.
5 The bacterium is killed and digested within the vesicle.

Fig. 5-23

DISTRIBUTION IN BODY

Macrophages are widely distributed, being essential component of many other tissues, in particular the blood cell forming tissues.

- **Liver- Kupffer cells**
- **Lungs- Alveolar macrophages/Dust cells**
- **Bone- Osteoclast**
- **CNS-Microgial cells**
- **Epidermis- Langerhans cells**

CELL TYPE	LOCATION	FUNCTION
Monocyte	Blood	Precursor of macrophages
Macrophage	Connective tissue, lymphoid organs, lungs	Production of cytokines, chemotactic factors, & several other molecules that mediate inflammation, antigen presentation
Kupffer Cell	Liver	Production of cytokines, chemotactic factors, & several other molecules that mediate inflammation, antigen presentation

Microglia Cell	Nerve tissue of CNS	Production of cytokines, chemotactic factors, & several other molecules that mediate inflammation, antigen presentation
Langerhans Cell	Skin	Antigen Presentation
Osteoclast	Bone	Bone Resorption
Multinuclear Giant Cell	Connective Tissue	Digestion of foreign bodies

LEUKOCYTES

Frequently found in connective tissue.

Migrate through the walls of capillaries from blood to the connective tissues, by a process called diapedesis.

Diapedesis increases during inflammation.

Leukocytes found in CT:-

1. Lymphocytes
2. Neutrophils
3. Eosinophils
4. Basophils

MAST CELLS

Oval to round cells

20-30μm in diameter

Cytoplasm is filled with basophilic granules.

Small & spherical nucleus is centrally located.

Function: storage of chemical mediators of the inflammatory response.

Granules are metachromatic.

Release histamine, neutral proteases, eosinophil chemotactic factor of anaphylaxis, leukotrienes.

2 types of mast cells:

Connective tissue mast cell: mainly contains heparin

Mucosal mast cell: granules contain chondroitin sulfate.

Originate from stem cells in the bone marrow.

Surface of mast cells contains specific receptors for IgE.

IgE molecules are bound to the surface of mast cells & blood basophils.

Widespread in the human body but are particularly abundant in the dermis& digestive & respiratory tracts.

PLASMA CELLS

Few plasma cells in most connective tissues.

Numerous in sites subject to penetration by bacteria & foreign particles & in areas of chronic inflammation.

Large, ovoid cells

Basophilic cytoplasm.

Nucleus is spherical & eccentrically placed, containing compact, coarse heterochromatin alternating with light areas.

Derived from B lypmhocytes

Responsible for the synthesis of antibodies.

Antibodies are immunoglobulins produced in response to penetration of antigens.

Each antibody is specific for the one antigen that gave rise to its production.

Antigen- antibody reaction has the capacity to neutralize harmful effects caused by antigens.

Antigen loses its capacity to do harm when it combines with its respective antibody.

Average life is 10-20 days.

TYPES OF CONNECTIVE TISSUE

Embryonal connective tissue:

Present during embryonic and fetal development.

When present post natally mesenchymal and mucus CT are associated with the healing of injured tissue.

Two types:

1. Mesenchymal CT:

Dominant connective tissue of young embryo.

With development it differentiates into smooth muscles, vascular and lymphatic channels and all of the CT types like cementum, dentin and pulp of teeth.

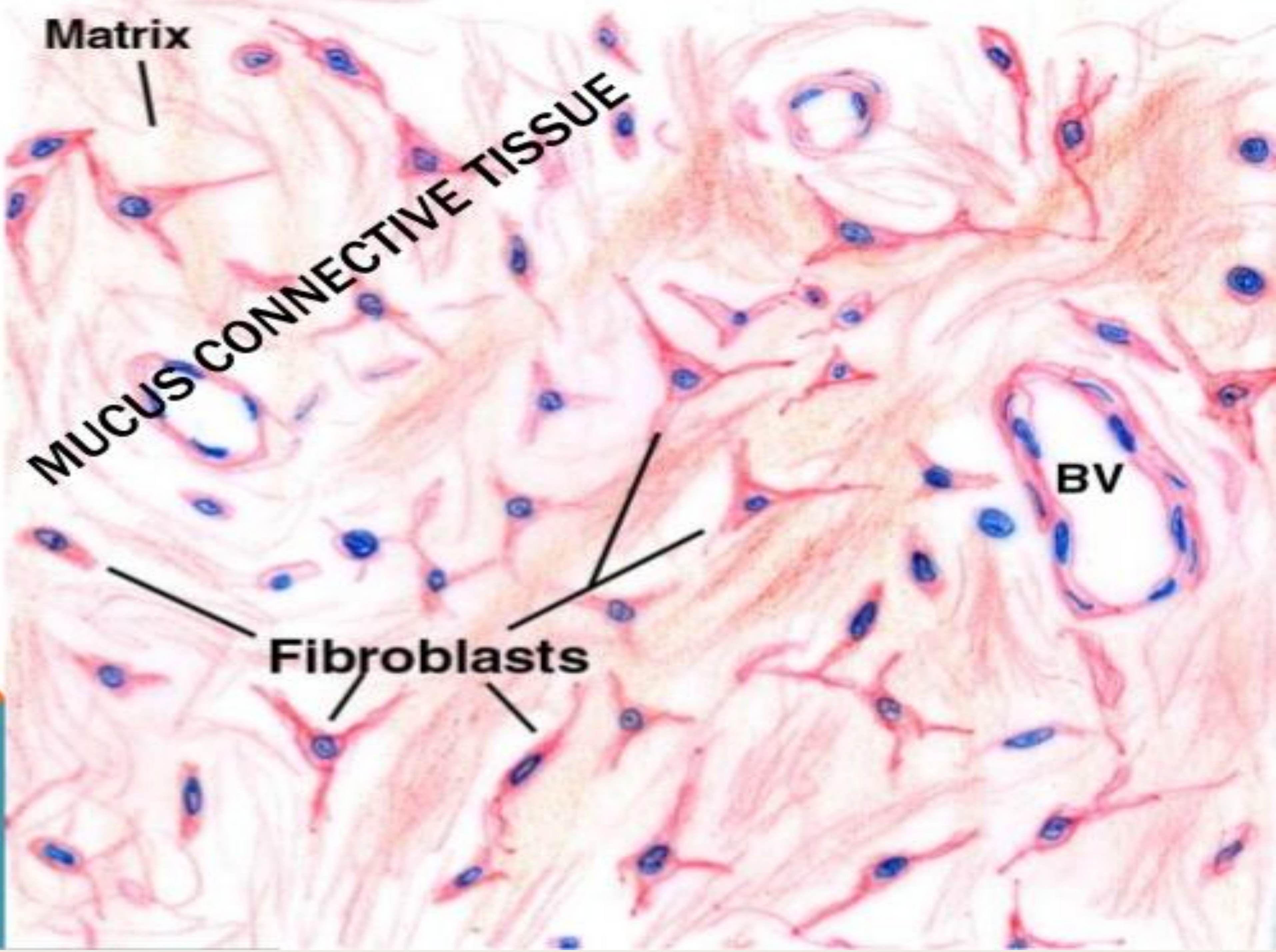
2. Mucus CT:

Intermediate stage between the mesenchyme and differentiated/adult tissue.

Found in the umbilical cord where it is known as wharton's jelly

Found in vitreous humous of eye and dental pulp.

Serves as a filler tissue.


Matrix
MUCUS CONNECTIVE TISSUE
BV
Fibroblasts

Regular connective tissue

Composed of two subtypes: loose and dense varieties.

Developmentally more advanced than the embryonal ones

In loose CT the fibrous elements are fewer and poorly organized

In dense CT the fiber component is compactly arranged with diminished spaces accommodating sparse amount of amorphous ground substance.

Loose Connective Tissue

Known as areolar (little spaces) connective tissue because of numerous voids or spaces in the tissue.

Distributed generally throughout the body.

It surrounds all blood vessels and nerves

Underlies all epithelial lining of respiratory and digestive tracts

Most common cell types are fibroblasts and macrophages.

Collagen fibres are most abundant, few reticular fibres are present

Collagen and elastic fibres course through the tissue haphazardly.

Functions

Support, packing, repair, protection of nerves, lymphatics and blood vessels

Defense against invasion of foreign bodies.

Repair function is facilitated by the presence of mesenchymal cells reserve which produce fibrillogenic and other CT cell components.

Role in the diffusion of oxygen, nutrients and metabolites.

Dense Connective Tissue

Fibrous elements are more numerous and densely packed.

Increase in fiber population

Decrease in the number of cells, ground substance and densities of blood and lymphatic vessels.

When the fibres are arranged into dense masses with specific orientation, the tissue is said to be regularly arranged DENSE CT otherwise it is designated as irregularly arranged DENSE CT.

DENSE REGULAR CONNECTIVE TISSUE

Characterized by orderly and densely packed arrays of fibres.

Cells are densely packed.

Forms very strong tough bands, sheets or cords.

Examples are:

Ligaments (which connect bone and supporting organ of abdominal cavity)

Tendons(which attach muscle to bone)

Aponeurosis (which links muscles).

DENSE IRREGULAR CONNECTIVE TISSUE

- **Fibers make up bulk of the tissue**
- **Arranged in bundles oriented in various directions.**
- **Cell population is sparse and typically of single type mainly fibroblasts.**
- **Less ground substance.**
- **Provides protective membrane and supportive framework for organs.**
- **In some organs such as kidney and glands they are called CAPSULES**
- **In others such as membranes loosely separating abdominal organs, they are called FASCIA.**
- **Membranes covering bone, cartilage, and muscle are known as SHEATHS.**
- **When they partition the organ into territories such as lobules of glands and lymphatic organs they are known as SEPTA.**

TYPES OF DENSE CONNECTIVE TISSUE

Dense irregular ct

- Fibres make up bulk of the tissue and arranged in bundles oriented in various directions
- Cell population is sparse and typically of single type mainly fibroblasts
- Ground substance is also less
- E.g submucosa in intestinal tract

Dense regular ct

- It is characterized by orderly and densely packed arrays of fibres.
- Cells are densely packed.
- Decrease no. of cells, ground substance, densities of blood and lymphatic vessels.
- It is main functional component of tendons. Ligaments and aponeurosis

SPECIAL FORMS OF CONNECTIVE TISSUE PROPER

Adipose connective tissue:

Fat cells or patches of adipocytes dispersed through most loose CT designated as adipose tissue.

Seen under the skin

Surrounds organs such as kidneys and suprarenals, grooves of heart, white bone marrow, mesenteries as well as axilliary, cervical and inguinal regions.

Cell shows a thin layer of cytoplasm as a ring around the vacuole left by the removed lipid droplet the so called signet ring cell.

Cell membrane includes a glycoprotein layer.

Cytoplasm contains golgi apparatus, mitochondria, a paucity of RER and ribosomes, vesicles of smooth endoplasmic reticulum and microtubules.

Adipose tissue is subdivided into incomplete lobules by a partition of CT containing blood vessels and nerves.

Reticular fibers branch from these partition and support individual fat cell.

Adipose tissue is richly vascularized.

TYPES OF ADIPOSE CONNECTIVE TISSUE

Unilocular or white adipose tissue:

Cell contain only one fat droplet in the cytoplasm.

1. **Yellow color is due to the presence of carotenoids.**

Cells are spherical when isolated

All adult tissue type is yellow type except lobule of auricle, scrotum, eyelids.

Multilocular or brown adipose tissue:

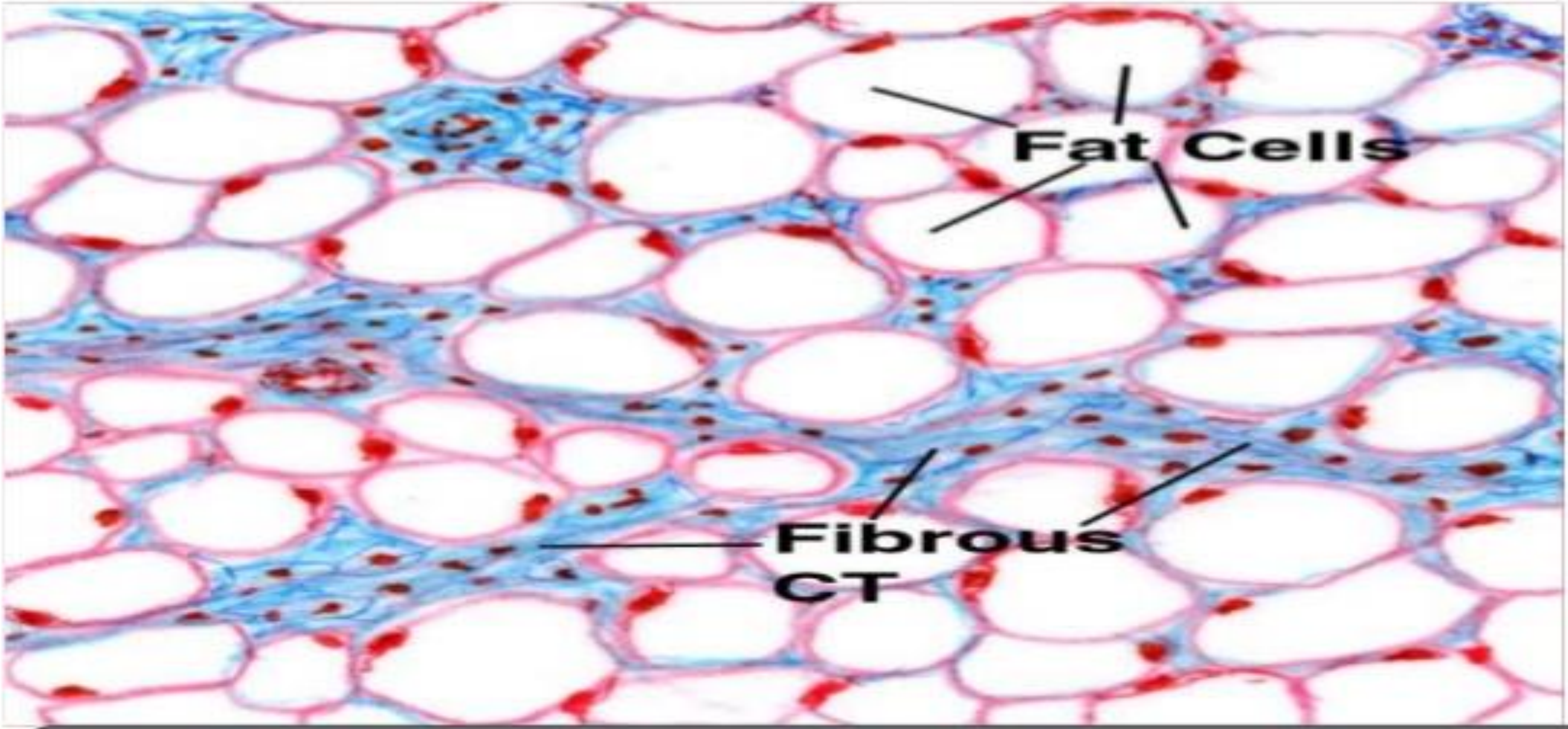
Cells are polygonal in shape and are smaller

Cytoplasm contain a great number of lipid droplets and numerous mitochondria.

RER and SER are not abundant.

Brown color is due to high content of cytochromes in mitochondria

Commonly seen in hibernating animals, embryo and newborn.



WHITE ADIPOSE TISSUE

RETICULAR CONNECTIVE TISSUE

Located in areas requiring a delicate matting/framework for support as in bone marrow, lymphoid organs, liver, spleen, lymph nodes, kidneys and endocrine glands.

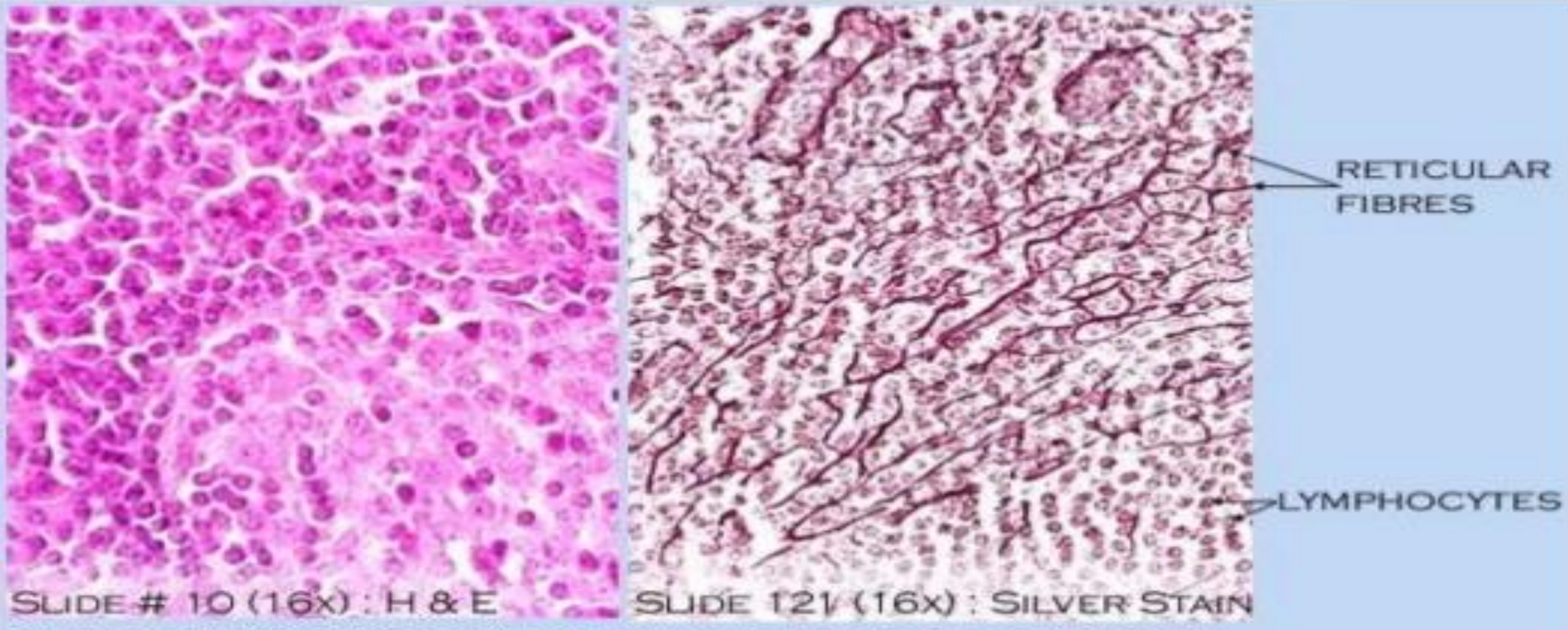
Fibres are arranged in a diffuse lacework or stroma

Support functional cell components of gland.

Reticulin fibres composed of protein called reticulin.

Reticular fibres are very fine with a diameter (0.2-0.5 micrometres).

Fibres are not visible in H & E preparations.



SLIDES # 10 & 121: LYMPH NODE - RETICULAR FIBRES

ELASTIC CONNECTIVE TISSUE

Predominance of elastic fibres, other fibres though present are reduced in number.

Color of elastic tissue is yellow

Fibres are arranged mostly in parallel though may join other bundle groups.

Fibre groups are supported by fibrocytes and collagen fibres.

Vascular and nerve supply is limited.

Fibres are elastic and may stretch atleast twice their length.

In living tissues they are pale yellow, with H & E stain they stain bright red.

High refractive index- darker than collagen fibres in unstained preparation

FINE STRUCTURE OF ELASTIC FIBRES

- Elastic fibres are single structure lacking any periodicity.
- Elastic fibres are composed of two components

Elastin

- Occupies central portion
- Rich in proline and glycine
- Poor in hydroxyproline n completely lacks hydroxylysine
- Stains pale because it has little affinity for heavy metal salts

Microfibrils

- A fibrillar glycoprotein
- Straight and thin
- Measuring12nm in diameter

PROELASTIN

Enzymatic removal of tail piece of molecule

TROPOELASTIN

4 tropoelastin molecules link together by lysine group by LYSYL OXIDASE

Desmosine and Isodesmosine

CLINICAL SIGNIFICANCE

MARFAN SYNDROME:

In marfan syndrome, a complex connective tissue disorder ,there is defect in fibrillin (a component of the microfibril) protein.

Abnormal elastic tissue.

SCLERODERMA:

Skin diseases associated with accumulation of elastin.

Structure, location , classification and function of muscular tissue

Muscle Tissue

- One of 4 primary tissue types, divided into:
  - skeletal muscle
  - cardiac muscle
  - smooth muscle

  Without these muscles, nothing in the body would move and no body movement would occur

Skeletal Muscles-
Organs of skeletal muscle tissue

- are attached to the skeletal system and allow us to move

- Muscular System- Includes only skeletal muscles

Skeletal Muscle Structures

- Muscle tissue (muscle cells or fibers)
- Connective tissues
- Nerves
- Blood vessels

6 Functions of Skeletal Muscles

1. Produce skeletal movement
2. Maintain body position and posture
3. Support soft tissues
4. Guard body openings (entrance/exit)
5. Maintain body temperature
6. Store Nutrient reserves

How is muscle tissue organized at the tissue level?

Organization of Connective Tissues

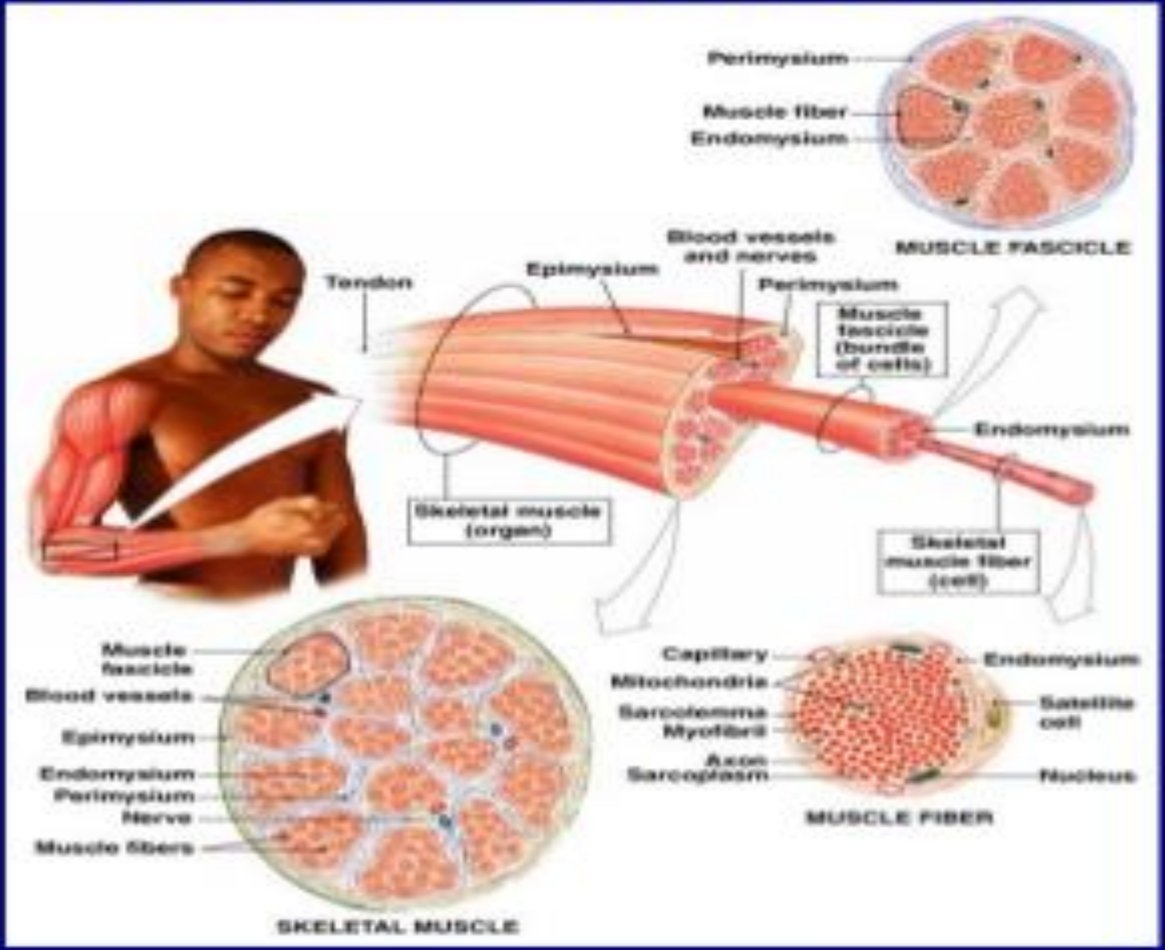


Figure 10-1

Organization of Connective Tissues

- Muscles have 3 layers of connective tissues:

1. Epimysium-Exterior collagen layer

- Connected to deep fascia
- Separates muscle from surrounding tissue

2. perimysium- Surrounds muscle fiber bundles (fascicles)

- Contains blood vessel and nerve supply to fascicles

3. endomysium

3. Endomysium

- Surrounds individual muscle cells (muscle fibers)
- Contains capillaries and nerve fibers contacting muscle cells
- Contains satellite cells (stem cells) that repair damage

Muscle Attachments

- Endomysium, perimysium, and epimysium come together:
  - at ends of muscles
  - to form connective tissue attachment to bone matrix
  - *i.e.*, tendon (bundle) or aponeurosis (sheet)

Nerves

Skeletal muscles are voluntary muscles, controlled by nerves of the central nervous system

Blood Vessels

- Muscles have extensive vascular systems that:
  - supply large amounts of oxygen
  - supply nutrients
  - carry away wastes

What are the characteristics of skeletal muscle fibers?

- Skeletal muscle cells are called fibers

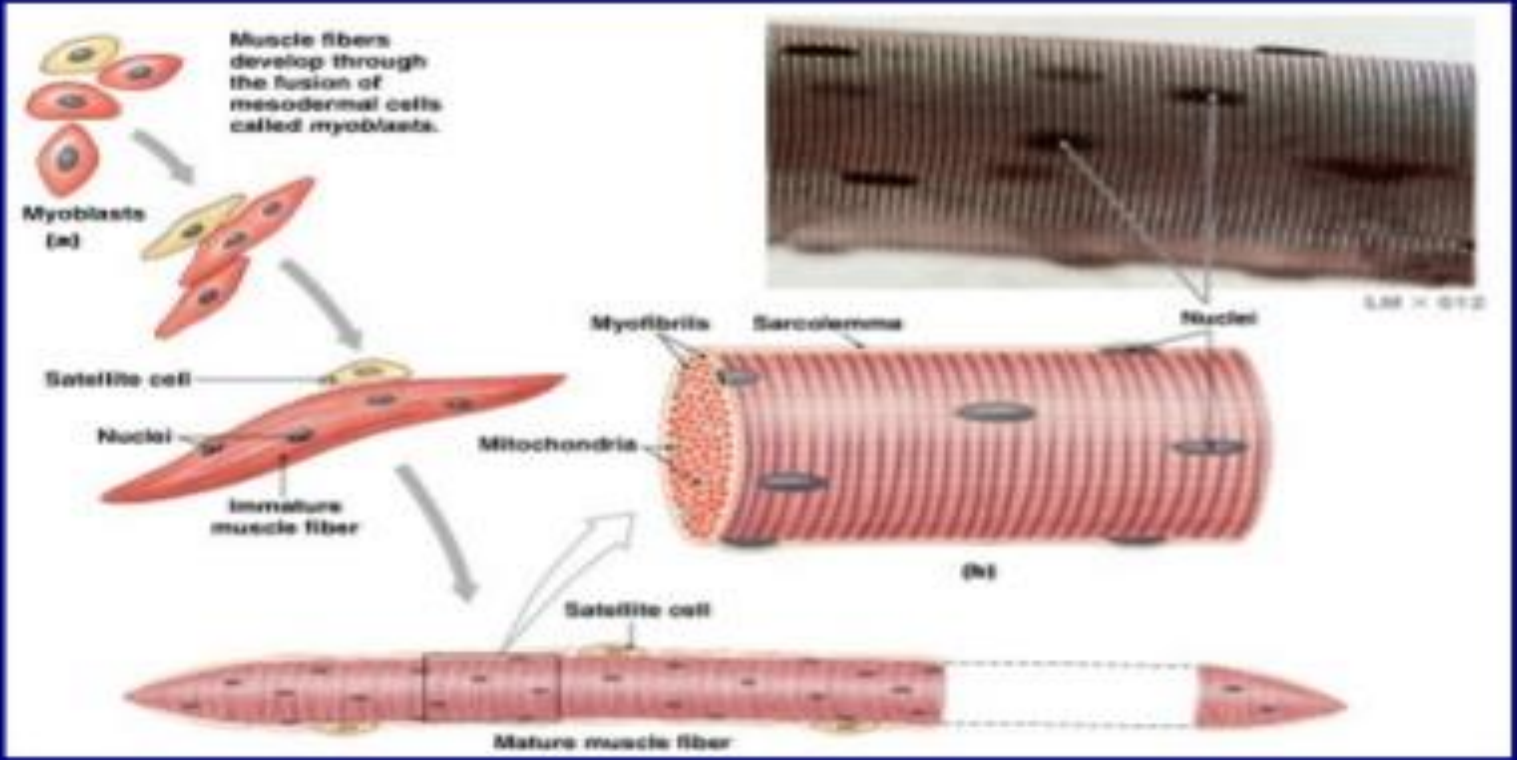


Figure 10-2

Skeletal Muscle Fibers

- Are very long
- Develop through fusion of mesodermal cells (myoblasts- embryonic cells))
- Become very large
- Contain hundreds of nuclei -multinucleate
- Unfused cells are satellite cells- assist in repair after injury

Organization of Skeletal Muscle Fibers

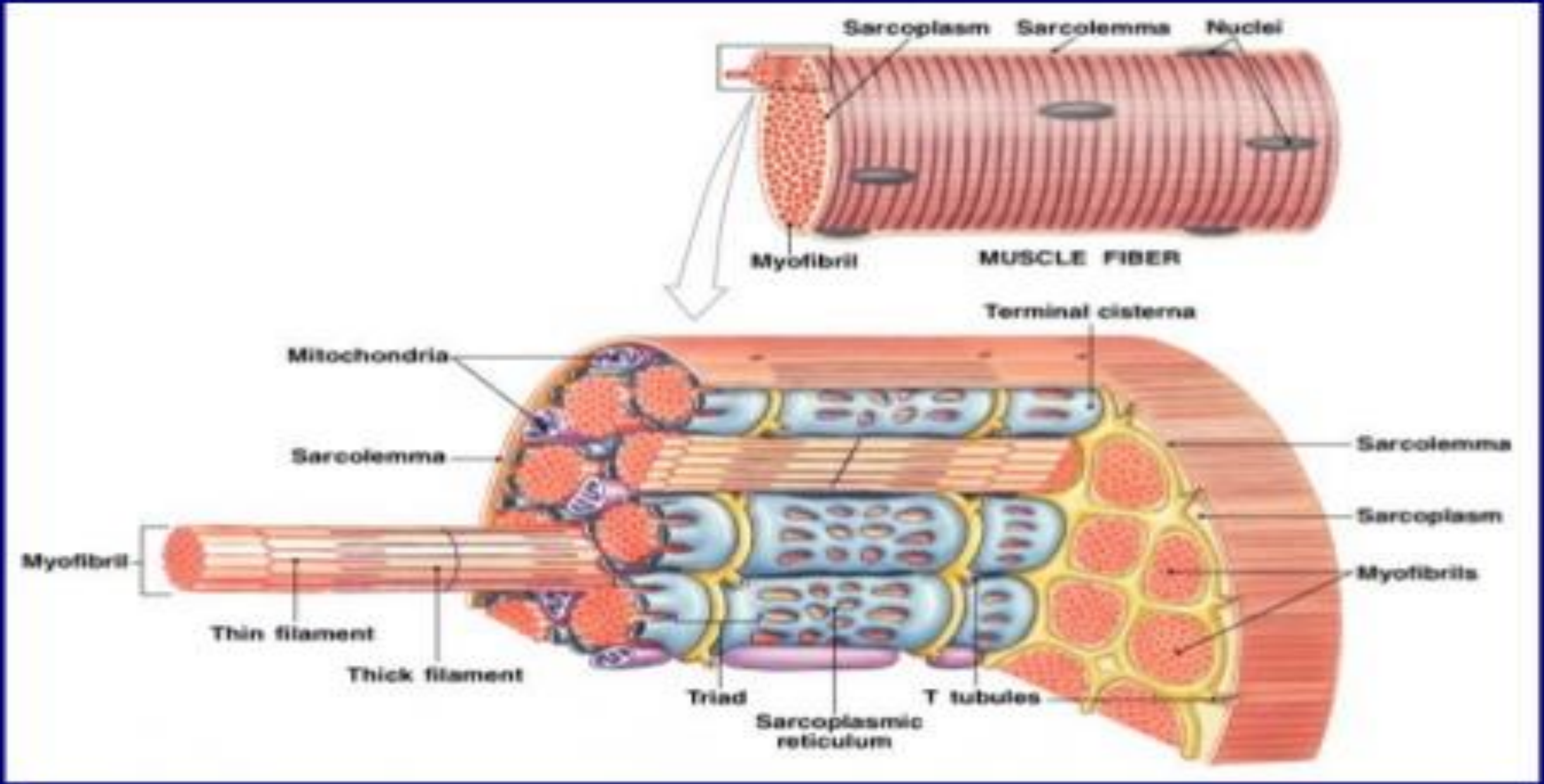


Figure 10-3

The Sarcolemma

- The cell membrane of a muscle cell
- Surrounds the sarcoplasm (cytoplasm of muscle fiber)
- A change in transmembrane potential begins contractions
- All regions of the cell must contract simultaneously

Transverse Tubules (T tubules)

- Transmit action potential - impulses through cell
- Allow entire muscle fiber to contract simultaneously
- Have same properties as sarcolemma
- Filled with extracellular fluid

Myofibrils- 1-2um in diameter

- Lengthwise subdivisions within muscle fiber
- Made up of bundles of protein filaments (myofilaments)
- Myofilaments - are responsible for muscle contraction

2 Types of Myofilaments

- Thin filaments:
  - made of the protein actin
- Thick filaments:
  - made of the protein myosin

Sarcoplasmic Reticulum (SR)

- A membranous structure surrounding each myofibril
- Helps transmit action potential to myofibril
- Similar in structure to smooth endoplasmic reticulum
- Forms chambers (terminal cisternae) attached to T tubules

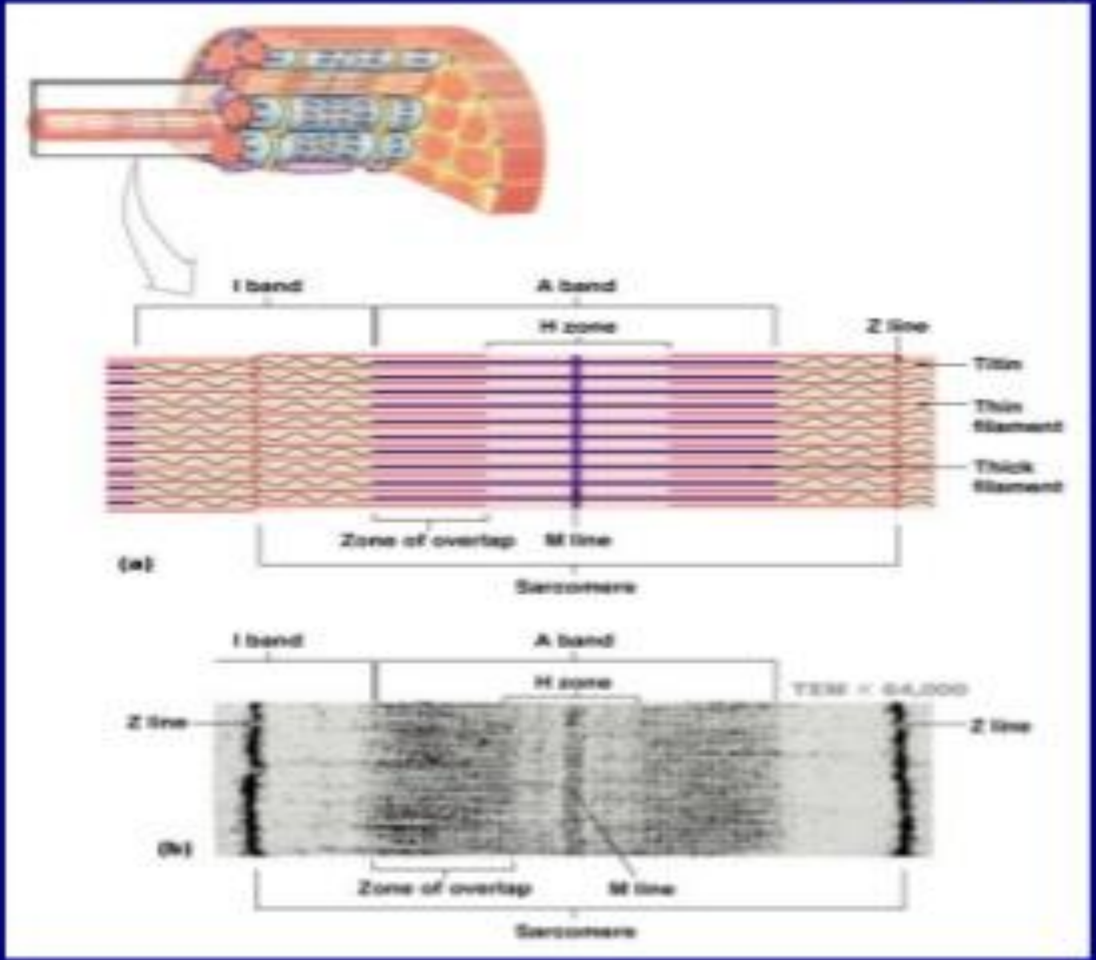
A Triad

- Is formed by 1 T tubule and 2 terminal cisterna

Cisternae

- Concentrate Ca^{2+} (*via* ion pumps)
- Release Ca^{2+} into sarcomeres to begin muscle contraction

Structural components of the Sarcomeres



- -The contractile units of muscle
- -Structural units of myofibrils
- -Form visible patterns within myofibrils

Figure 10-4

Muscle Striations

- A striped or striated pattern within myofibrils:
  - alternating dark, thick filaments (A bands) and light, thin filaments (I bands)

M Lines and Z Lines

- M line:
  - the center of the A band
  - at midline of sarcomere
- Z lines:
  - the centers of the I bands
  - at 2 ends of sarcomere

Zone of Overlap

- The densest, darkest area on a light micrograph
- Where thick and thin filaments overlap

The H Zone

- The area around the M line
- Has thick filaments but no thin filaments

Titin

- Are strands of protein
- Reach from tips of thick filaments to the Z line
- Stabilize the filaments

Sarcomere Structure

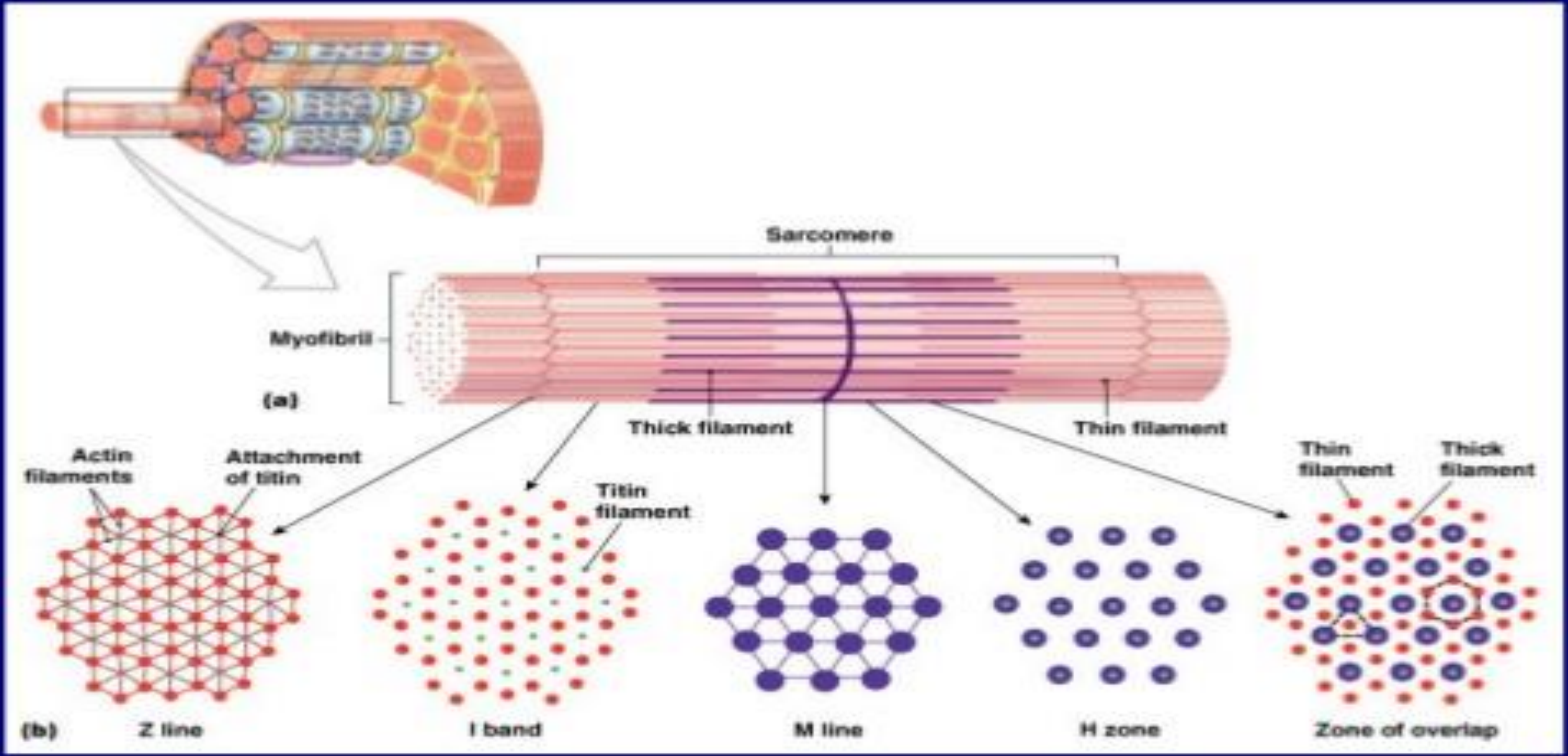


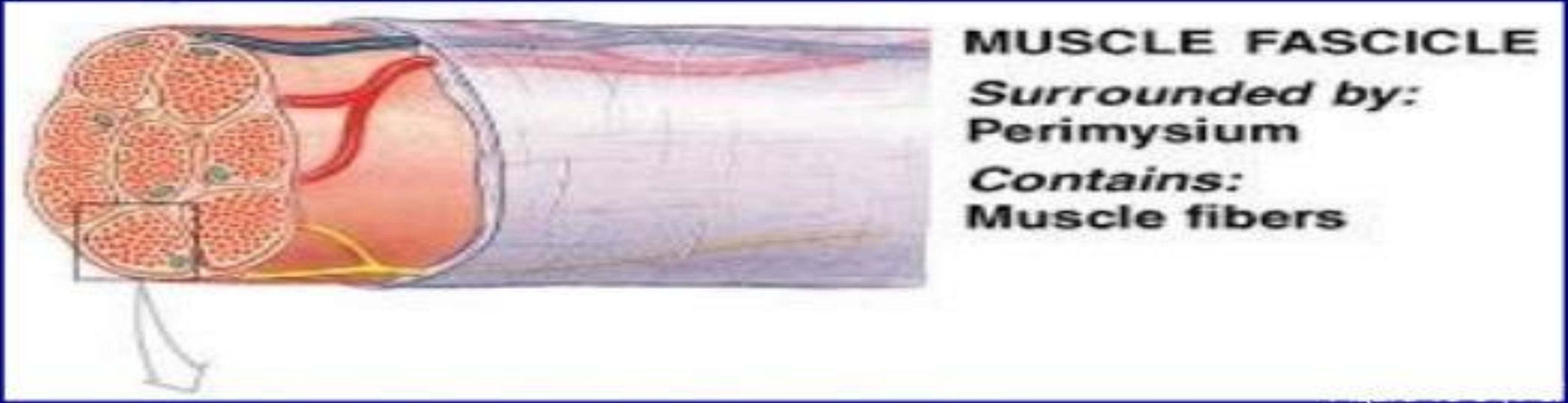
Figure 10-5

Sarcomere Function

- Transverse tubules encircle the sarcomere near zones of overlap
- Ca^{2+} released by SR causes thin and thick filaments to interact

Level 1: Skeletal Muscle

Level 2: Muscle Fascicle



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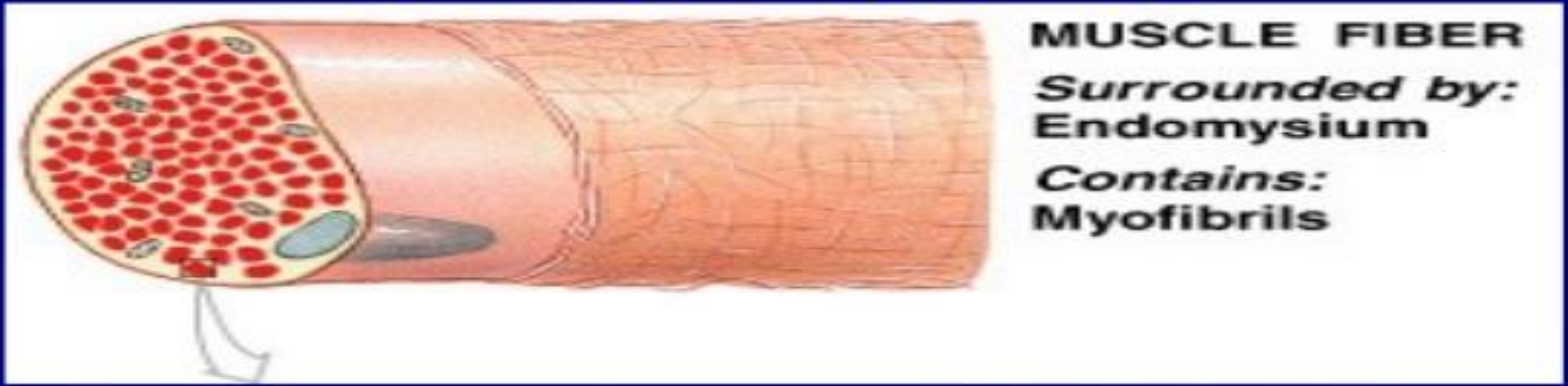
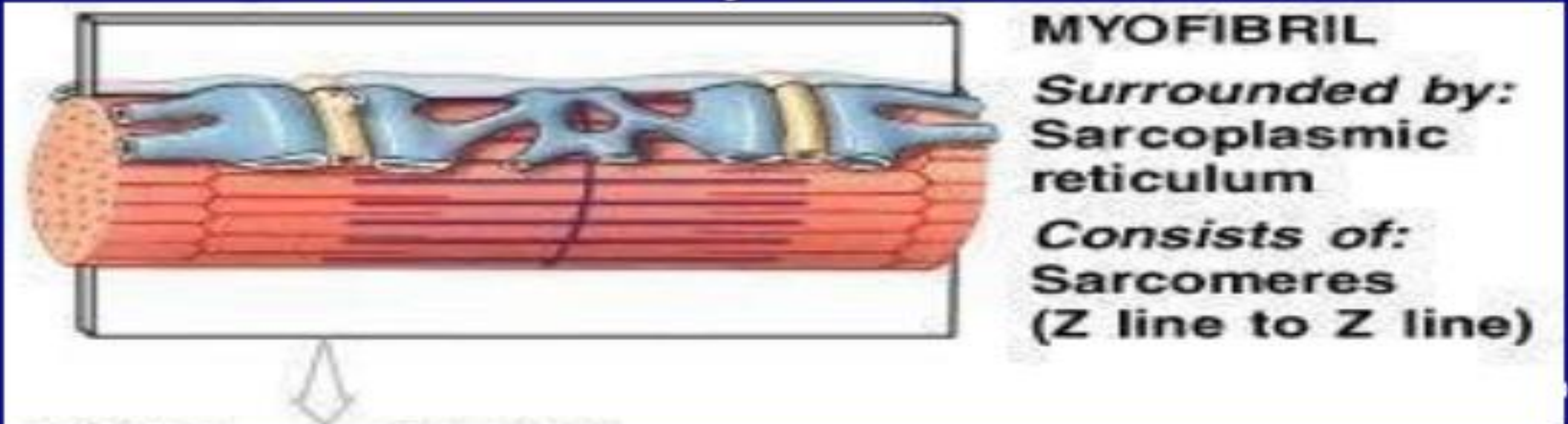
Level 3: Muscle Fiber



Level 4: Myofibril



Level 5: Sarcomere

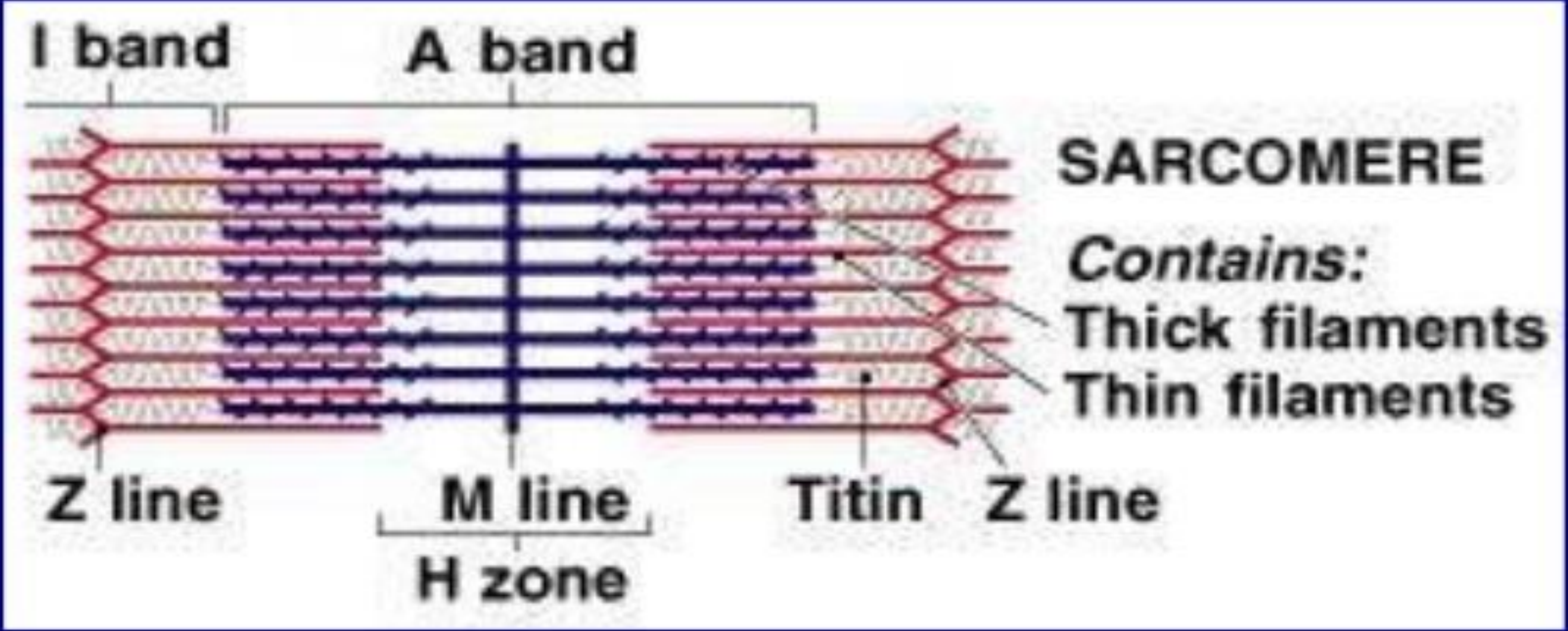


Figure 10-6 (5 of 5)

Muscle Contraction

- Is caused by interactions of thick and thin filaments
- Structures of protein molecules detemine interactions

A Thin Filament

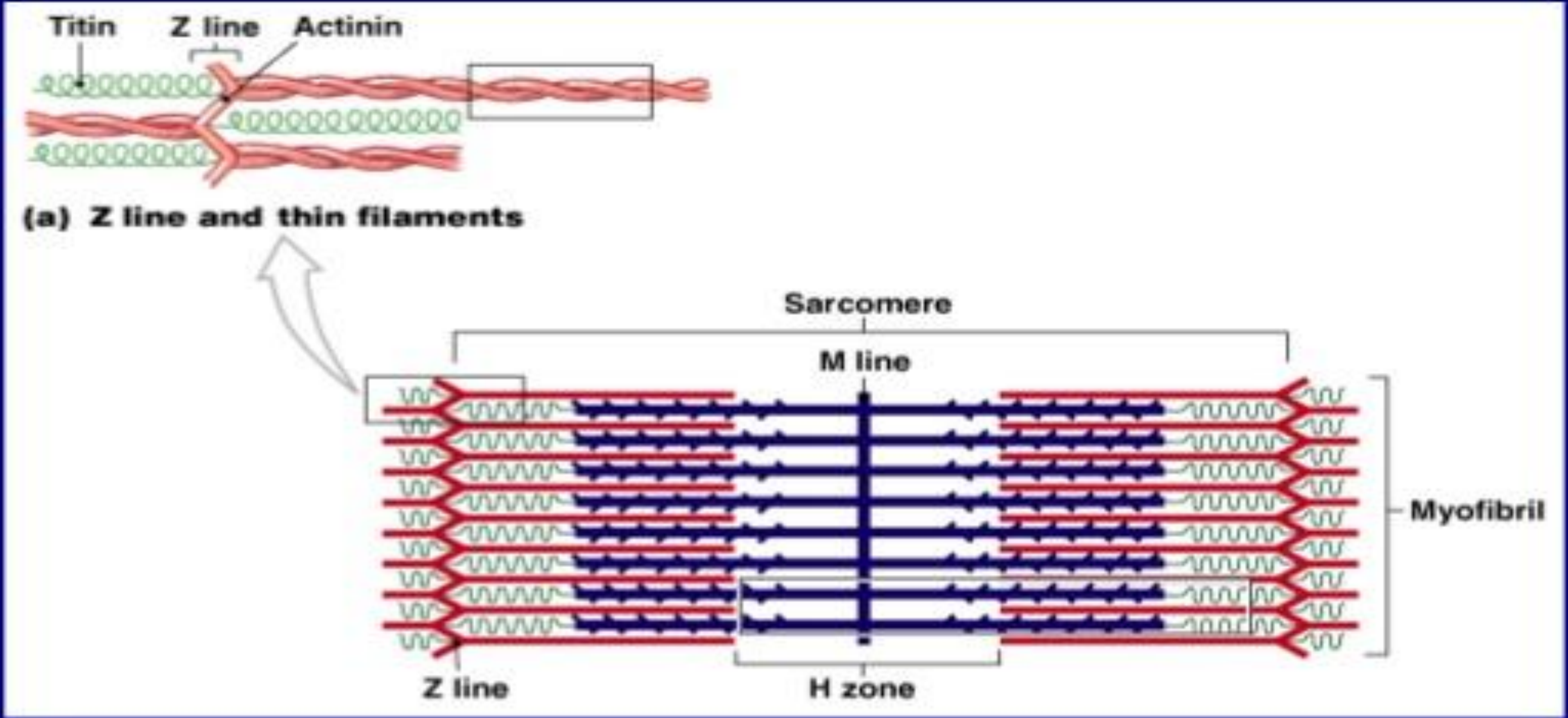
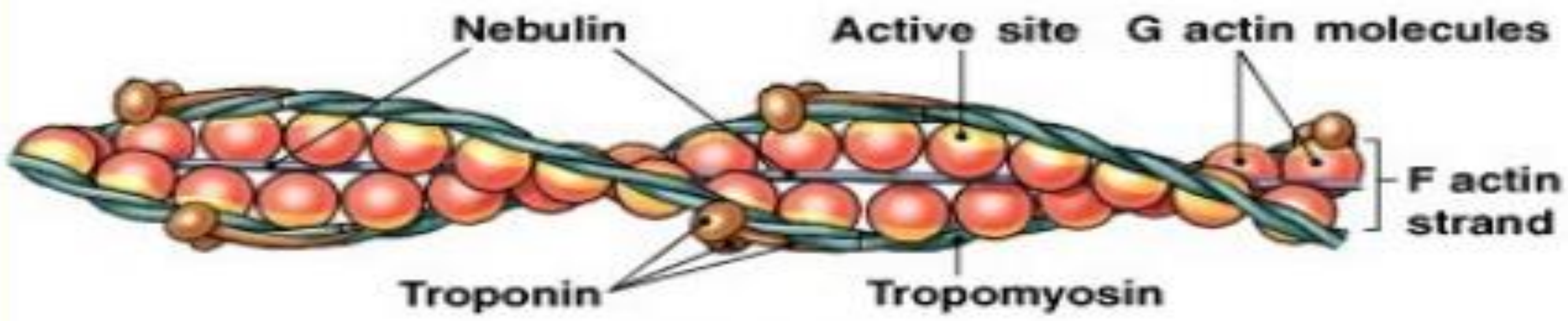


Figure 10-7a

4 Thin Filament Proteins

1. F actin:
   - is 2 twisted rows of globular G actin
   - the active sites on G actin strands bind to myosin
2. Nebulin:
   - holds F actin strands together
3. Tropomyosin:
   - is a double strand
   - prevents actin-myosin interaction
4. Troponin:
   - a globular protein
   - binds tropomyosin to G actin
   - controlled by Ca^{2+}

Troponin and Tropomyosin



(b) Thin filament

Initiating Contraction

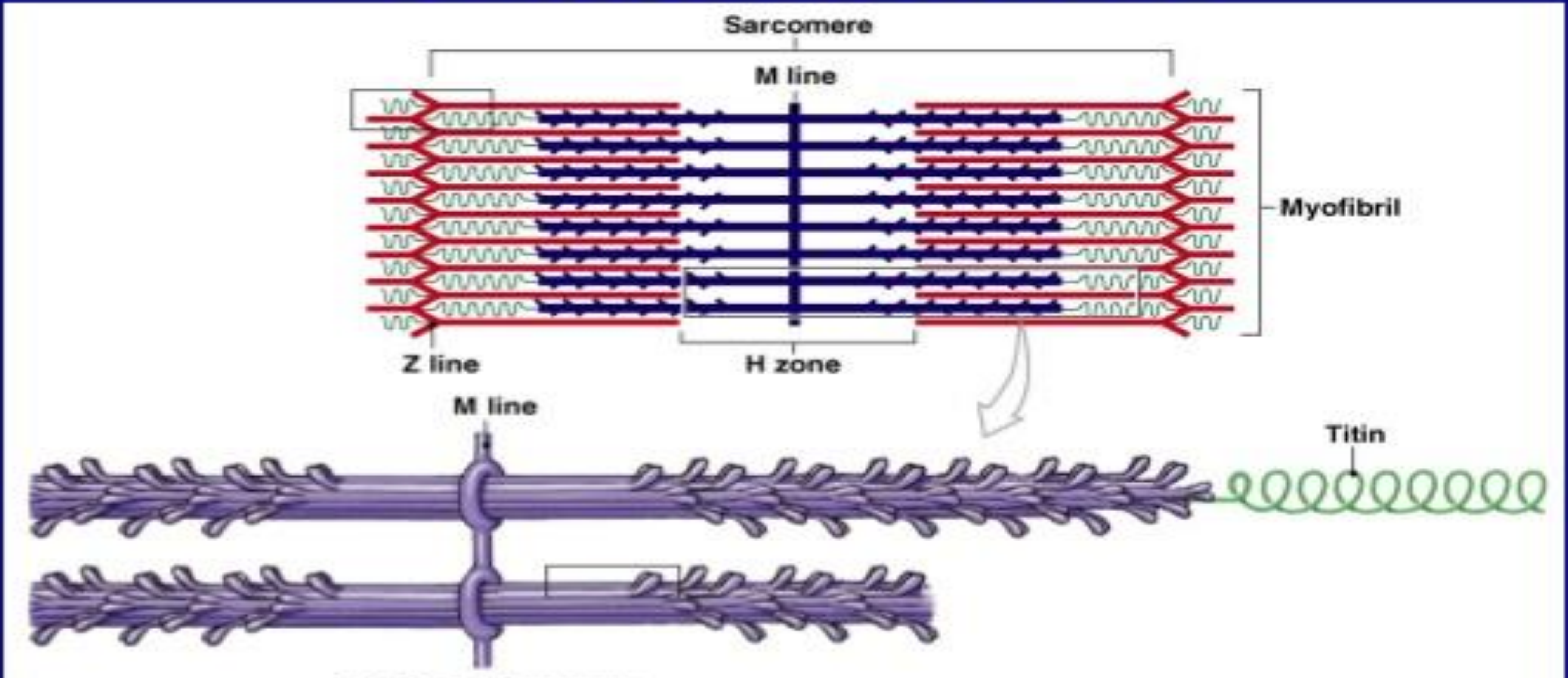
Ca2+ binds to receptor on troponin molecule

Troponin–tropomyosin complex changes

Exposes active site of F actin

Figure 10-7b

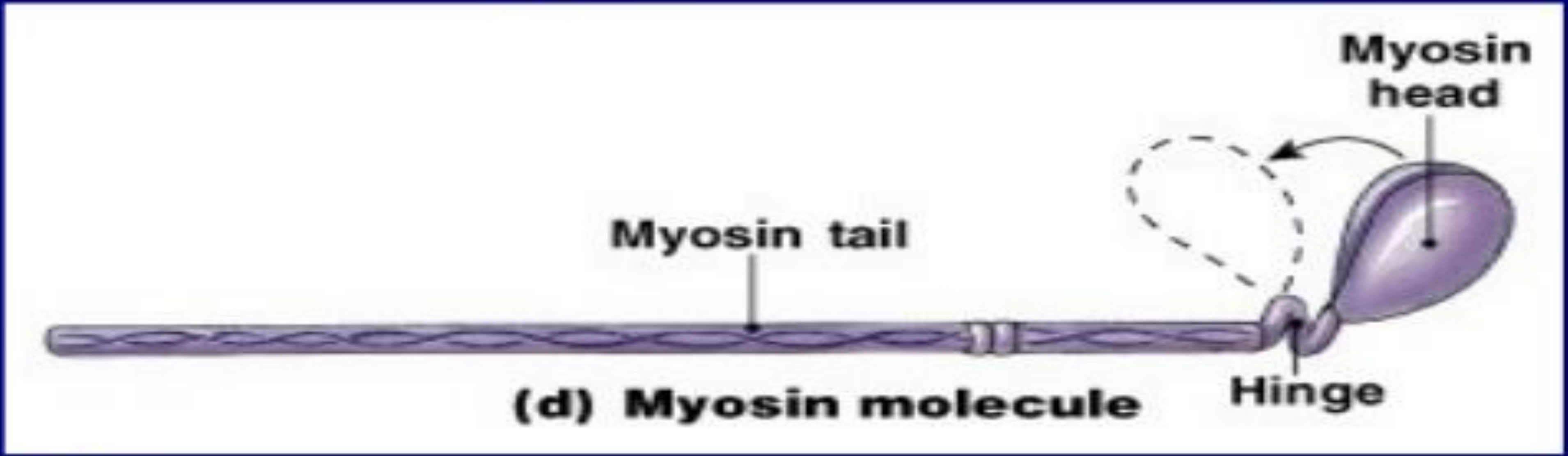
A Thick Filament



(c) Thick filaments

Contain twisted myosin subunits
Contain titin strands that recoil after stretching

The Mysosin Molecule



- Tail:
  - binds to other myosin molecules
- Head:
  - made of 2 globular protein subunits
  - reaches the nearest thin filament

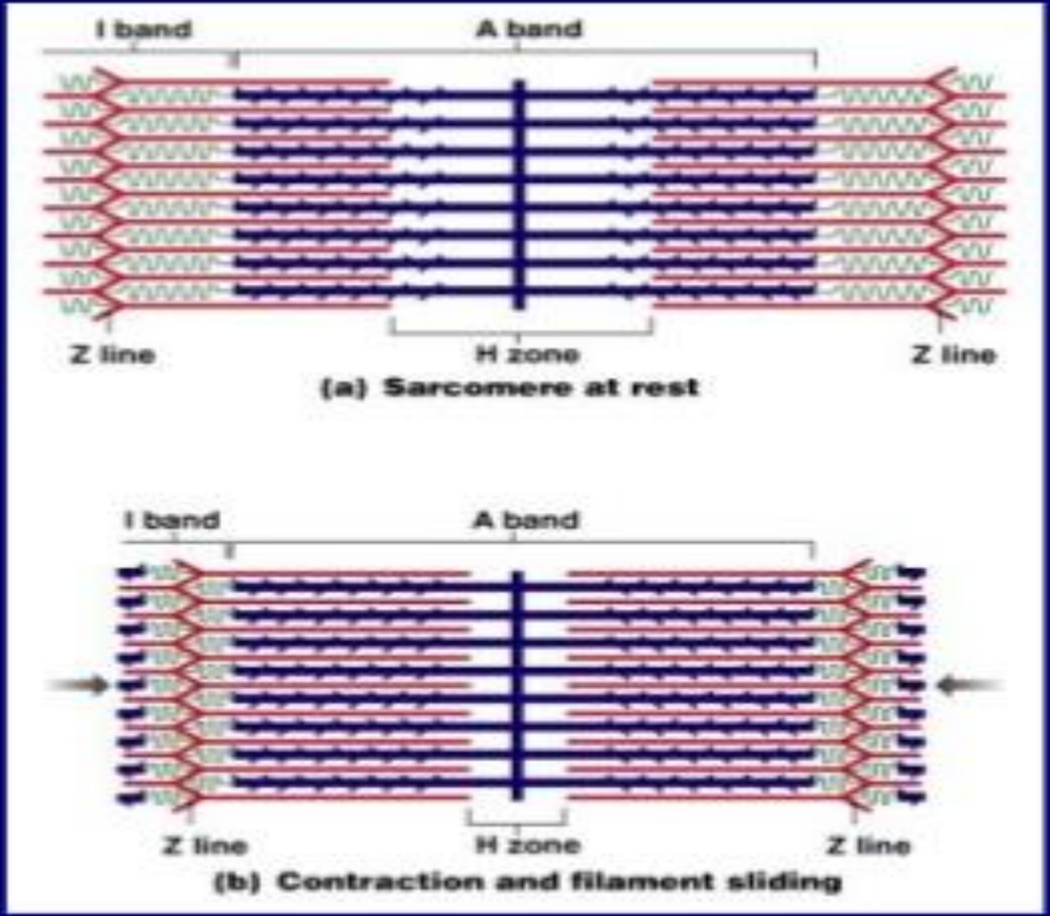
Mysosin Action

- During contraction, myosin heads:
  - interact with actin filaments, forming cross-bridges
  - pivot, producing motion

Skeletal Muscle Contraction

- Sliding filament theory:
  - thin filaments of sarcomere slide toward M line
  - between thick filaments
  - the width of A zone stays the same
  - Z lines move closer together

Sliding Filaments



What are the components of the neuromuscular junction, and the events involved in the neural control of skeletal muscles?

Skeletal Muscle Contraction

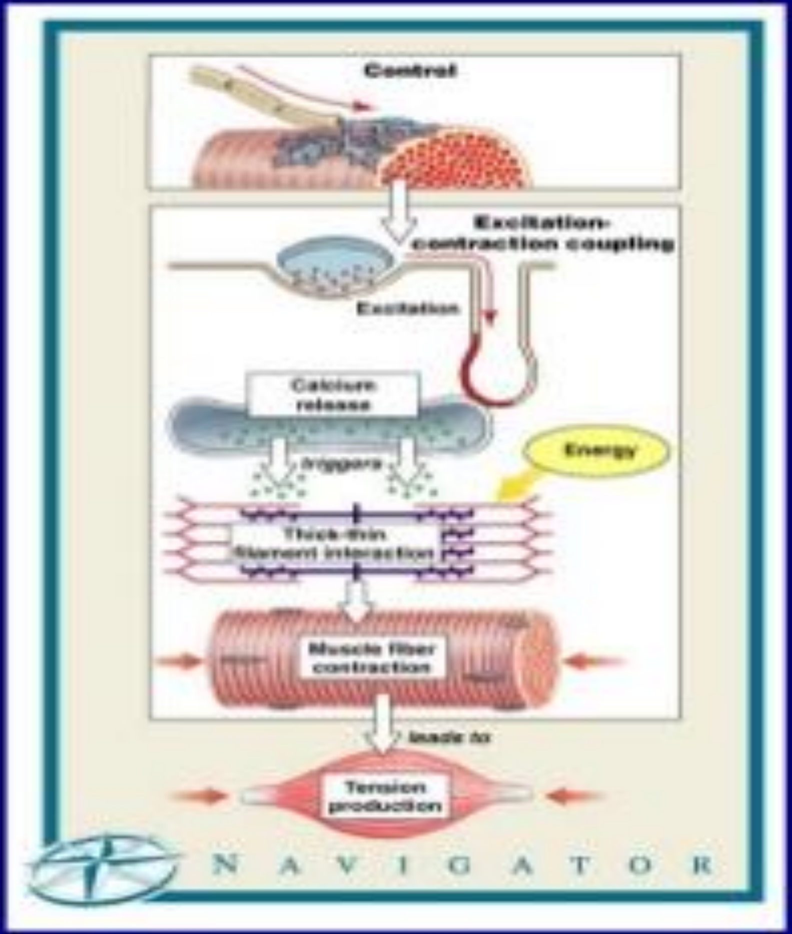


Figure 10-9 (Navigator)

The Process of Contraction

- Neural stimulation of sarcolemma:
  - causes excitation-contraction coupling
- Cisternae of SR release Ca^{2+}:
  - which triggers interaction of thick and thin filaments
  - consuming ATP and producing tension

Skeletal Muscle Innervation

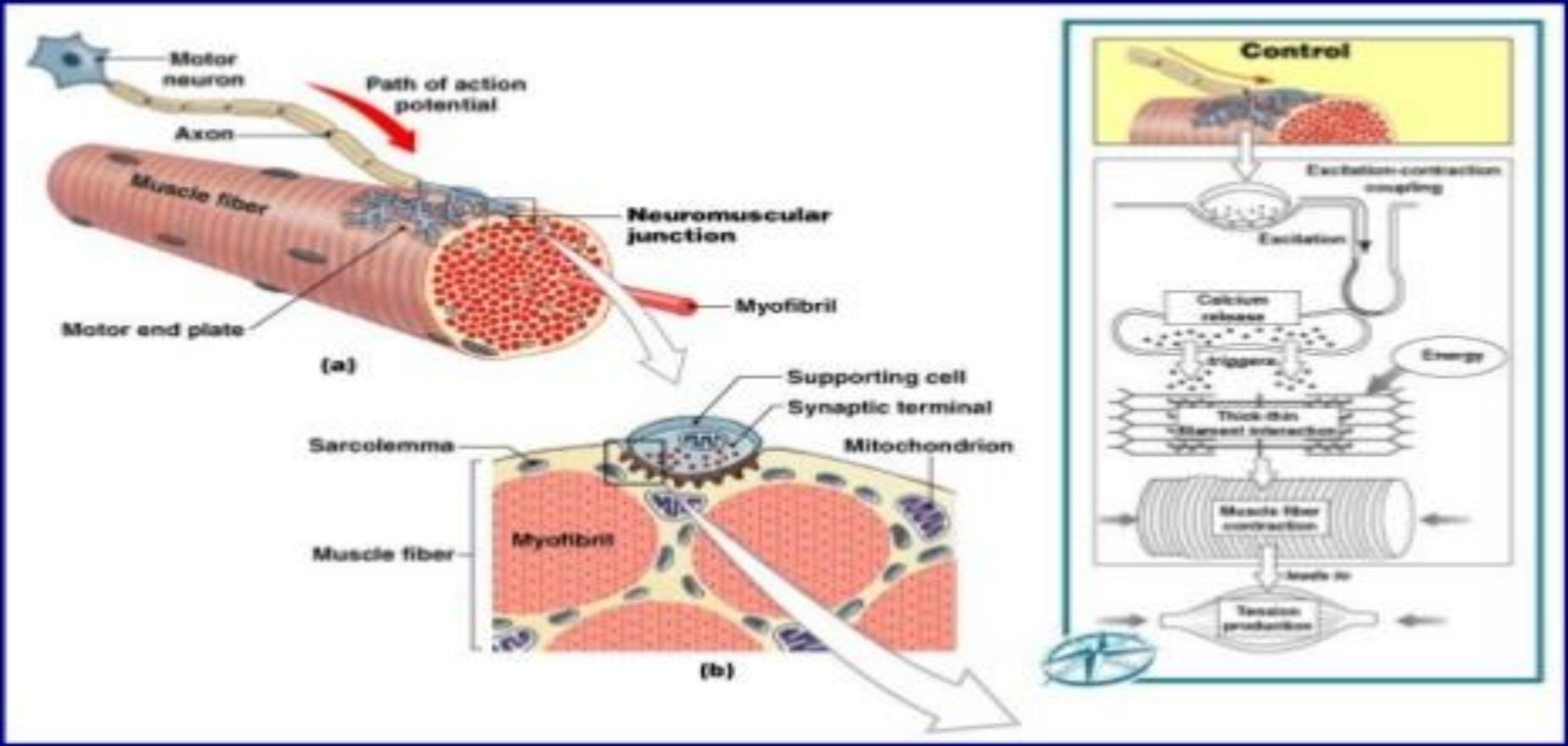


Figure 10-10a, b (Navigator)

The Neuromuscular Junction

- Is the location of neural stimulation
- Action potential (electrical signal):
  - travels along nerve axon
  - ends at synaptic terminal

Synaptic Terminal

- Releases neurotransmitter (acetylcholine or ACh)
- Into the synaptic cleft (gap between synaptic terminal and motor end plate)

The Neurotransmitter

- Acetylcholine or ACh:
  - travels across the synaptic cleft
  - binds to membrane receptors on sarcolemma (motor end plate)
  - causes sodium-ion rush into sarcoplasm
  - is quickly broken down by enzyme (acetylcholinesterase or AChE)

Action Potential

- Generated by increase in sodium ions in sarcolemma
- Travels along the T tubules
- Leads to *excitation-contraction coupling*

Excitation–Contraction Coupling

- Action potential reaches a triad:
  - releasing Ca^{2+}
  - triggering contraction
- Requires myosin heads to be in "cocked" position:
  - loaded by ATP energy

key steps involved in contraction of a skeletal muscle fiber

Exposing the Active Site

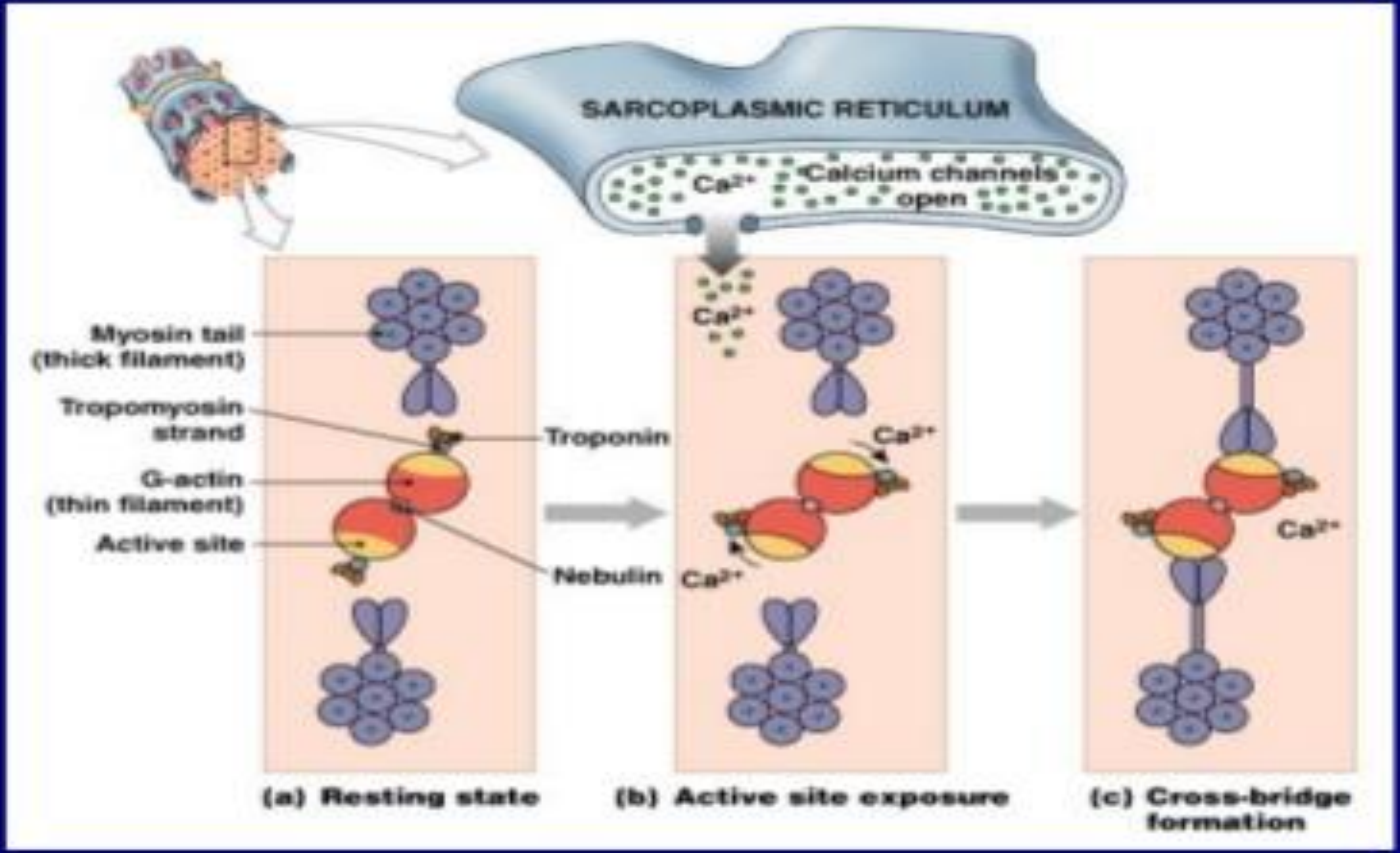


Figure 10-11

The Contraction Cycle

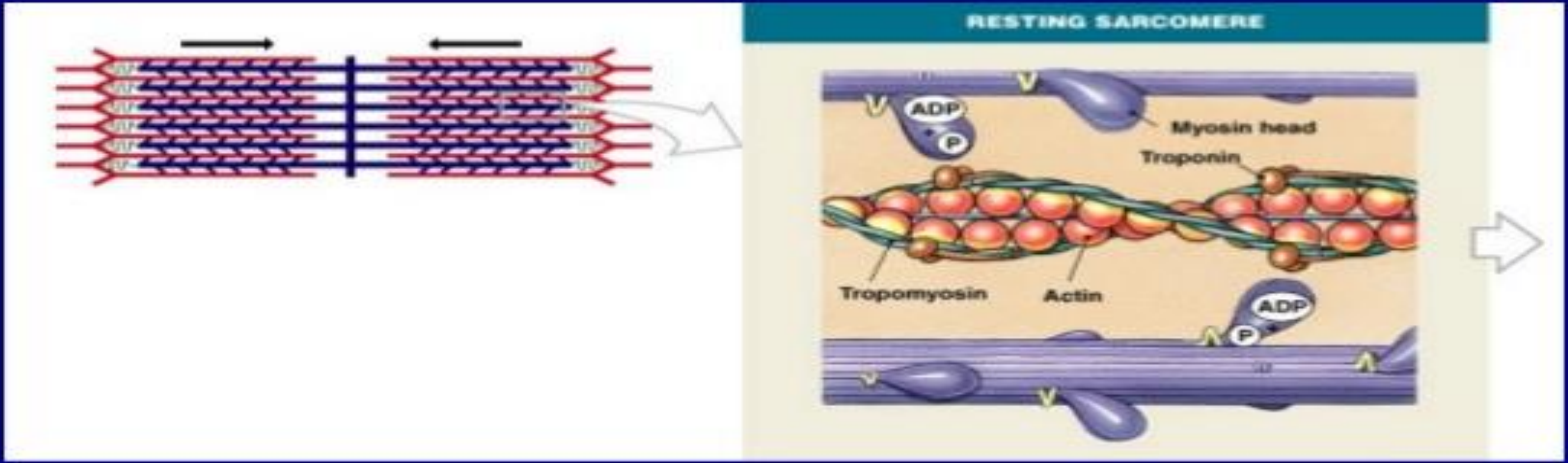


Figure 10-12 (1 of 4)

The Contraction Cycle

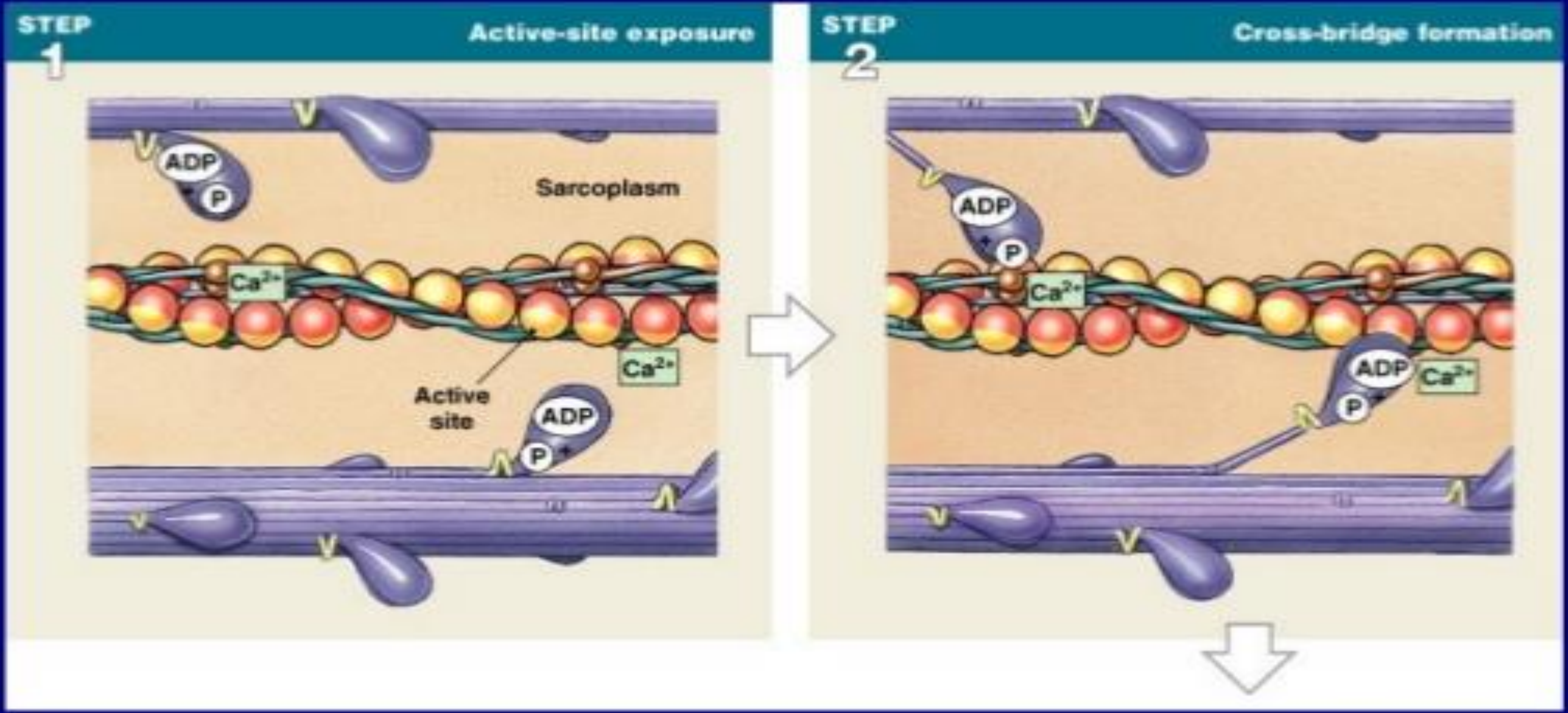


Figure 10-12 (2 of 4)

The Contraction Cycle

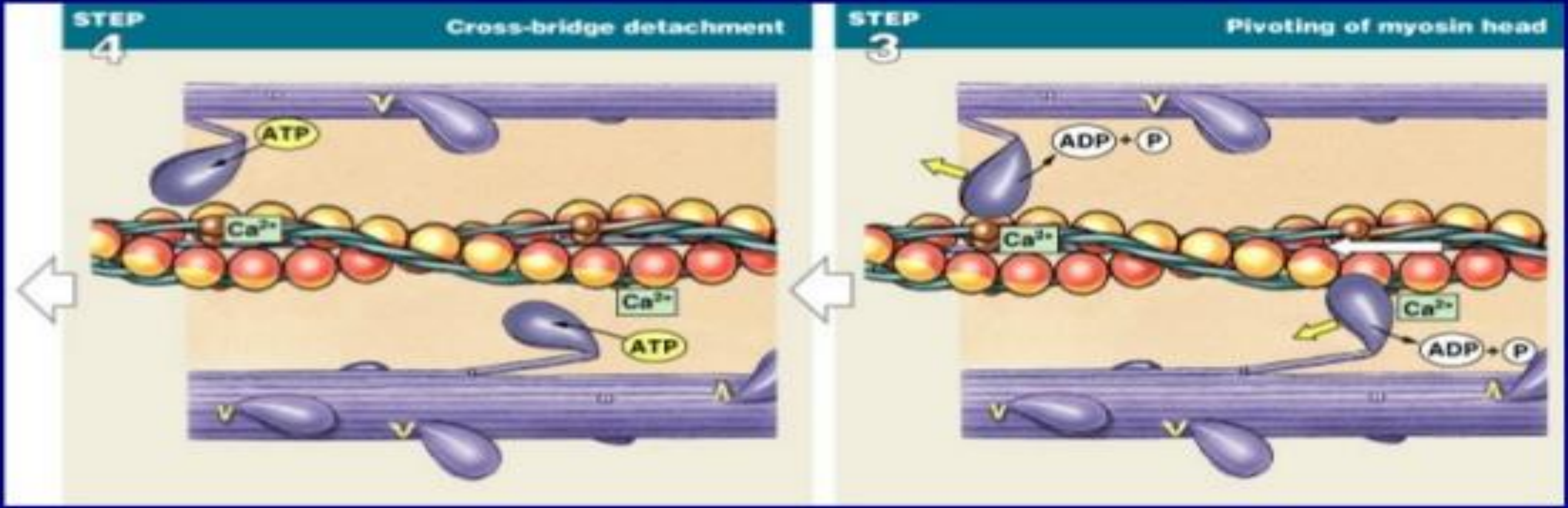


Figure 10-12 (3 of 4)

5 Steps of the Contraction Cycle

1. Exposure of active sites
2. Formation of cross-bridges
3. Pivoting of myosin heads
4. Detachment of cross-bridges
5. Reactivation of myosin

Contraction Duration

- Depends on:
  - duration of neural stimulus
  - number of free calcium ions in sarcoplasm
  - availability of ATP

Relaxation

- Ca^{2+} concentrations fall
- Ca^{2+} detaches from troponin
- Active sites are recovered by tropomyosin
- Sarcomeres remain contracted

Rigor Mortis

- A fixed muscular contraction after death
- Caused when:
  - ion pumps cease to function
  - calcium builds up in the sarcoplasm

KEY CONCEPT

- Skeletal muscle fibers shorten as thin filaments slide between thick filaments
- Free Ca^{2+} in the sarcoplasm triggers contraction
- SR releases Ca^{2+} when a motor neuron stimulates the muscle fiber
- Contraction is an active process
- Relaxation and return to resting length is passive

What is the mechanism responsible for tension production in a muscle fiber, and what factors determine the peak tension developed during a contraction?

Tension Production

- The all-or-none principal:
  - as a whole, a muscle fiber is either contracted or relaxed

Tension of a Single Muscle Fiber

- Depends on:
  - the number of pivoting cross-bridges
  - the fiber's resting length at the time of stimulation
  - the frequency of stimulation

Length-Tension Relationship

- Number of pivoting cross-bridges depends on:
  - amount of overlap between thick and thin fibers
- Optimum overlap produces greatest amount of tension:
  - too much or too little reduces efficiency
- Normal resting sarcomere length:
  - is 75% to 130% of optimal length

Frequency of Stimulation

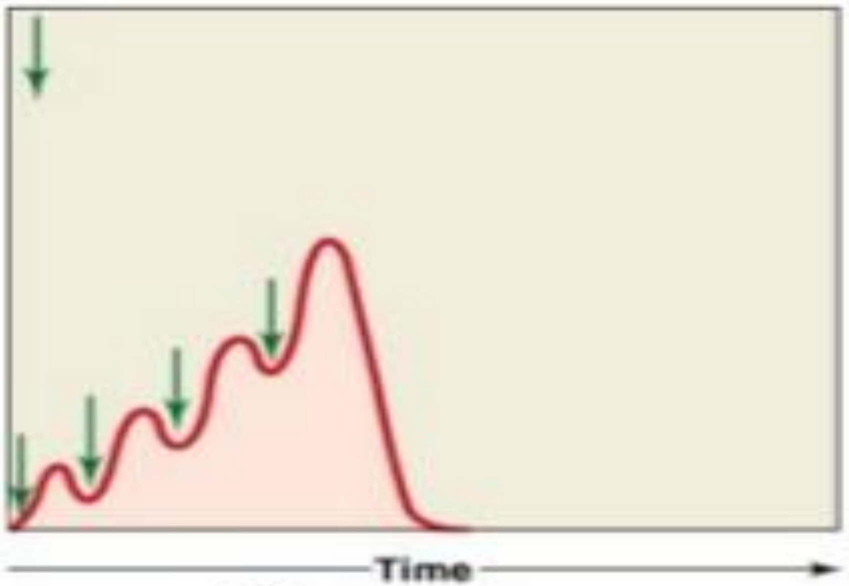
- A single neural stimulation produces:
  - a single contraction or twitch
  - which lasts about 7–100 msec
- Sustained muscular contractions:
  - require many repeated stimuli

3 Phases of Twitch

1. Latent period before contraction:
   - the action potential moves through sarcolemma
   - causing Ca^{2+} release
2. Contraction phase:
   - calcium ions bind
   - tension builds to peak
3. Relaxation phase:
   - Ca^{2+} levels fall
   - active sites are covered
   - tension falls to resting levels

Wave Summation

- Increasing tension or summation of twitches



(b)

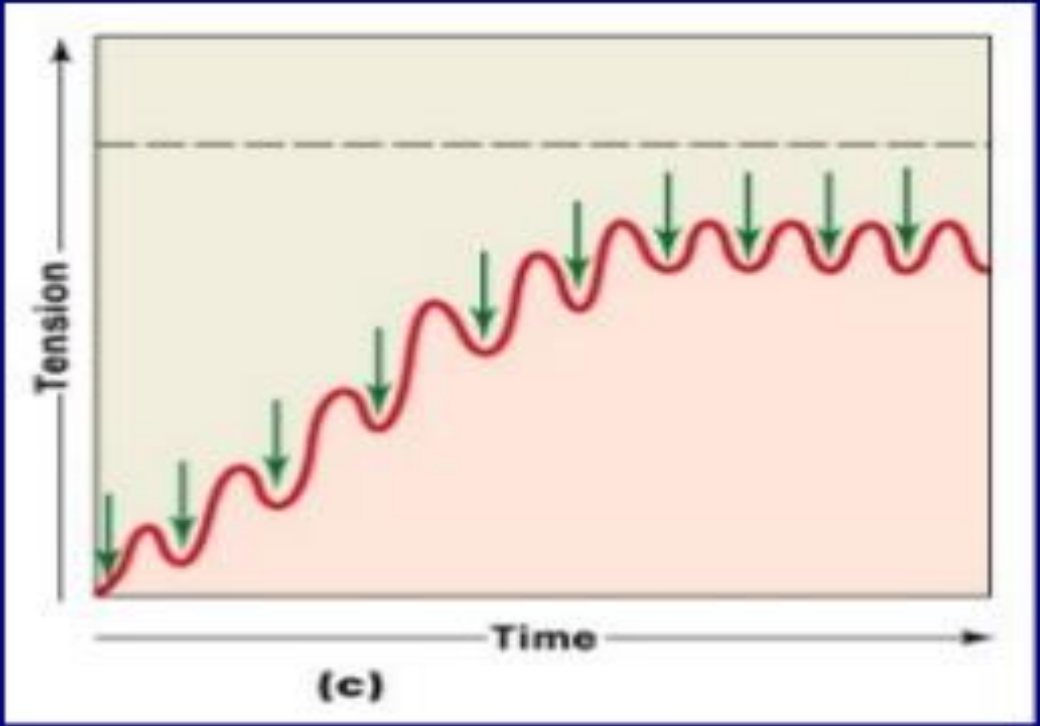
Figure 10-16b

Wave Summation

- Repeated stimulations *before the end* of relaxation phase:
  - stimulus frequency > 50/second
- Causes increasing tension or summation of twitches

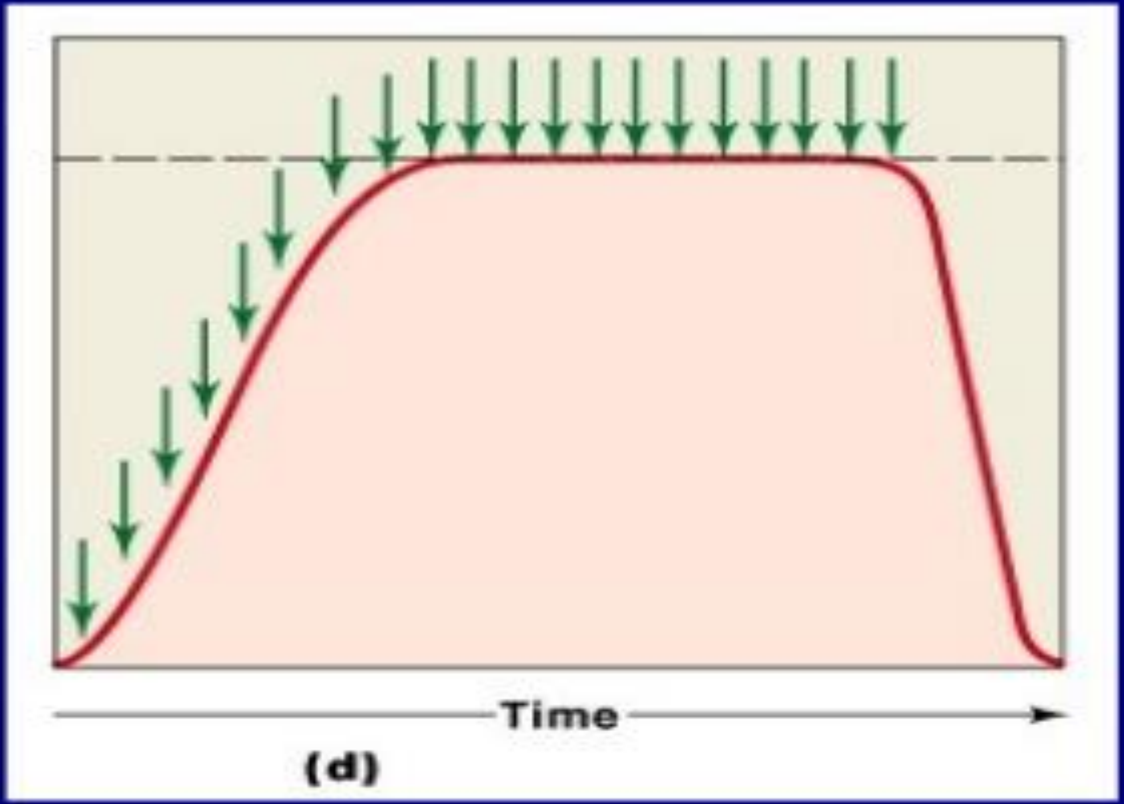
Incomplete Tetanus

Twitches reach maximum tension



- If rapid stimulation continues and muscle is not allowed to relax, twitches reach maximum level of tension

Complete Tetanus



- If stimulation frequency is high enough, muscle never *begins* to relax, and is in continuous contraction

What factors affect peak tension production during the contraction of an entire skeletal muscle, and what is the significance of the motor unit in this process?

Tension Produced by Whole Skeletal Muscles

- Depends on:
  - internal tension produced by muscle fibers
  - external tension exerted by muscle fibers on elastic extracellular fibers
  - total number of muscle fibers stimulated

PLAY InterActive Physiology: Contraction of Whole Muscle

Motor Units in a Skeletal Muscle

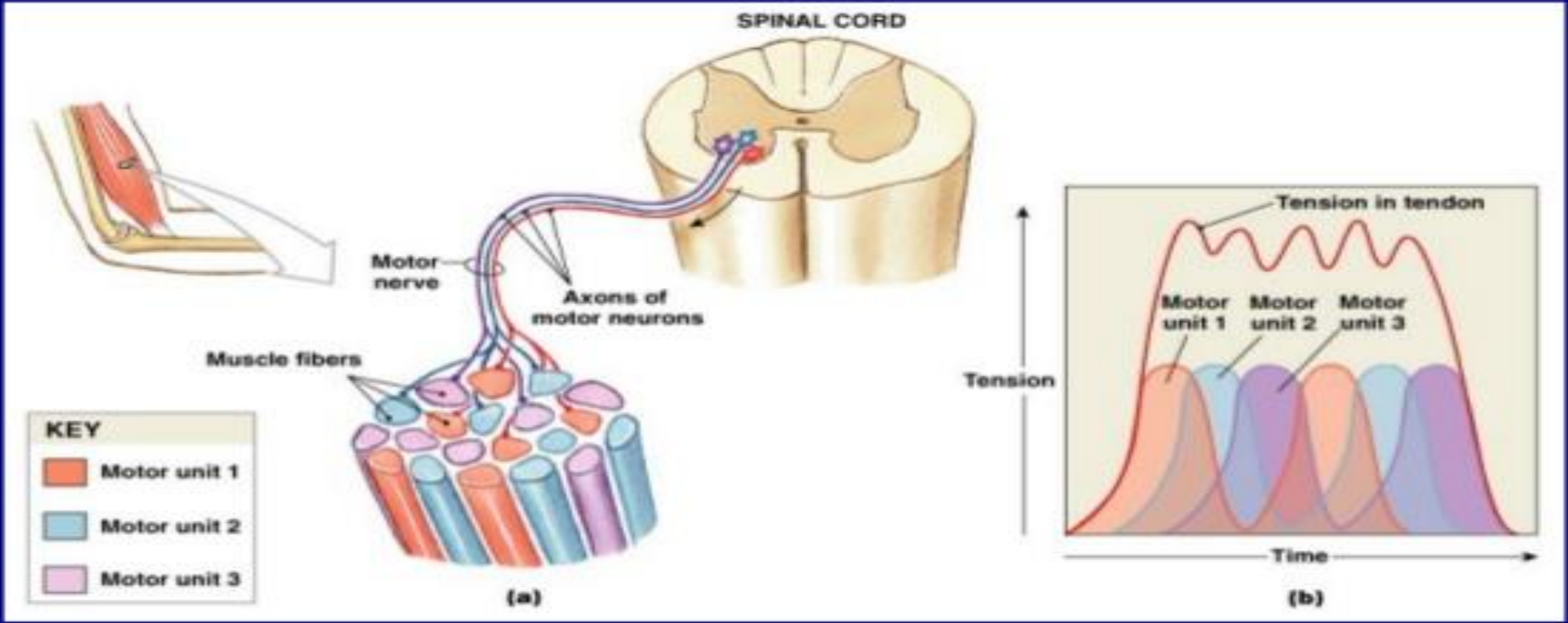


Figure 10-17

Motor Units in a Skeletal Muscle

- Contain hundreds of muscle fibers
- That contract at the same time
- Controlled by a single motor neuron

PLAY InterActive Physiology: Contraction of Motor Units

Recruitment (Multiple Motor Unit Summation)

- In a whole muscle or group of muscles, smooth motion and increasing tension is produced by slowly increasing size or number of motor units stimulated

Maximum Tension

- Achieved when all motor units reach tetanus
- Can be sustained only a very short time
- ## Sustained Tension
- Less than maximum tension
- Allows motor units to rest in rotation

KEY CONCEPT

- Voluntary muscle contractions involve sustained, tetanic contractions of skeletal muscle fibers
- Force is increased by increasing the number of stimulated motor units (recruitment)

Muscle Tone

- The normal tension and firmness of a muscle at rest
- Muscle units actively maintain body position, without motion
- Increasing muscle tone increases metabolic energy used, even at rest

What are the types of muscle contractions, and how do they differ?

2 Types of Skeletal Muscle Tension

- Isotonic contraction
- Isometric contraction

Isotonic Contraction

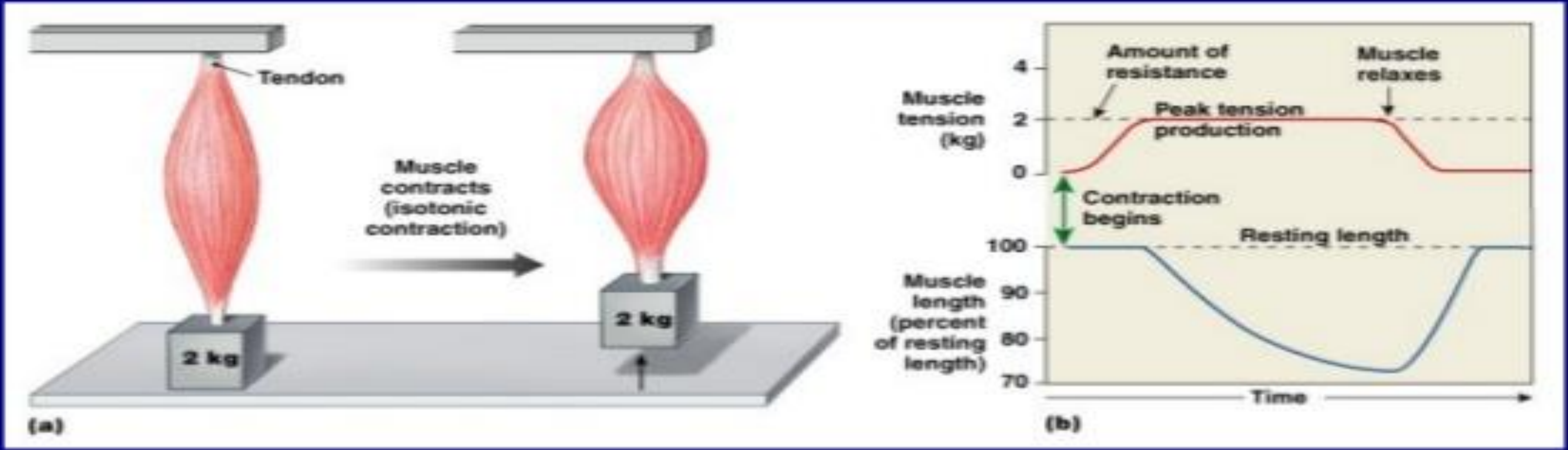


Figure 10-18a, b

Isotonic Contraction

- Skeletal muscle changes length:
  - resulting in motion
- If muscle tension > resistance:
  - muscle shortens (concentric contraction)
- If muscle tension < resistance:
  - muscle lengthens (eccentric contraction)

Isometric Contraction

- Skeletal muscle develops tension, but is prevented from changing length

Note: *Iso* = same, *metric* = measure

Resistance and Speed of Contraction

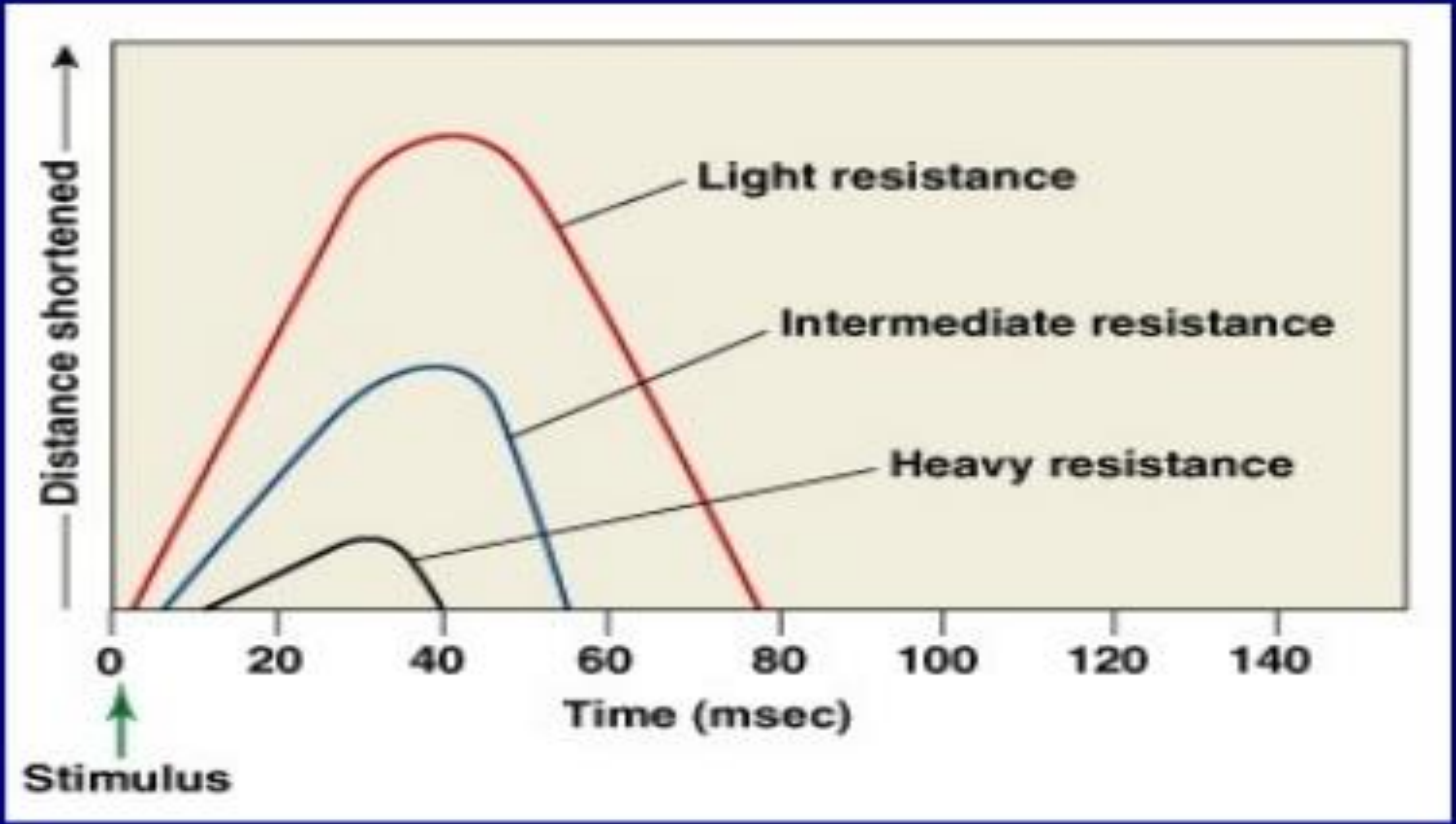


Figure 10-19

Resistance and Speed of Contraction

- Are inversely related
- The heavier the resistance on a muscle:
  - the longer it takes for shortening to begin
  - and the less the muscle will shorten

Muscle Relaxation

- After contraction, a muscle fiber returns to resting length by:
  - elastic forces
  - opposing muscle contractions
  - gravity

Elastic Forces

- The pull of elastic elements (tendons and ligaments)
- Expands the sarcomeres to resting length

Opposing Muscle Contractions

- Reverse the direction of the original motion
- Are the work of opposing skeletal muscle pairs

Gravity

- Can take the place of opposing muscle contraction to return a muscle to its resting state

What are the mechanisms by which muscle fibers obtain energy to power contractions?

ATP and Muscle Contraction

- Sustained muscle contraction uses a lot of ATP energy
- Muscles store enough energy to start contraction
- Muscle fibers must manufacture more ATP as needed

ATP and CP Reserves

- Adenosine triphosphate (ATP):
  - the active energy molecule
- Creatine phosphate (CP):
  - the storage molecule for excess ATP energy in resting muscle

Recharging ATP

- Energy recharges ADP to ATP:
  - using the enzyme creatine phosphokinase (CPK)
- When CP is used up, other mechanisms generate ATP

ATP Generation

- Cells produce ATP in 2 ways:
  - aerobic metabolism of fatty acids in the mitochondria
  - anaerobic glycolysis in the cytoplasm

Aerobic Metabolism

- Is the primary energy source of resting muscles
- Breaks down fatty acids
- Produces 34 ATP molecules per glucose molecule

Anaerobic Glycolysis

- Is the primary energy source for peak muscular activity
- Produces 2 ATP molecules per molecule of glucose
- Breaks down glucose from glycogen stored in skeletal muscles

Energy Use and Muscle Activity

- At peak exertion:
  - muscles lack oxygen to support mitochondria
  - muscles rely on glycolysis for ATP
  - pyruvic acid builds up, is converted to lactic acid

What factors contribute to muscle fatigue, and what are the stages and mechanisms involved in muscle recovery?

Muscle Fatigue

- When muscles can no longer perform a required activity, they are fatigued

Results of Muscle Fatigue

1. Depletion of metabolic reserves
2. Damage to sarcolemma and sarcoplasmic reticulum
3. Low pH (lactic acid)
4. Muscle exhaustion and pain

The Recovery Period

- The time required after exertion for muscles to return to normal
- Oxygen becomes available
- Mitochondrial activity resumes

The Cori Cycle

- The removal and recycling of lactic acid by the liver
- Liver converts lactic acid to pyruvic acid
- Glucose is released to recharge muscle glycogen reserves

Oxygen Debt

- After exercise:
  - the body needs more oxygen than usual to normalize metabolic activities
  - resulting in heavy breathing

KEY CONCEPT

- Skeletal muscles at rest metabolize fatty acids and store glycogen
- During light activity, muscles generate ATP through anaerobic breakdown of carbohydrates, lipids or amino acids
- At peak activity, energy is provided by anaerobic reactions that generate lactic acid as a byproduct

Heat Production and Loss

- Active muscles produce heat
- Up to 70% of muscle energy can be lost as heat, raising body temperature

Hormones and Muscle Metabolism

- Growth hormone
- Testosterone
- Thyroid hormones
- Epinephrine

How do the types of muscle fibers relate to muscle performance?

Muscle Performance

- Power:
  - the maximum amount of tension produced
- Endurance:
  - the amount of time an activity can be sustained
- Power and endurance depend on:
  - the types of muscle fibers
  - physical conditioning

3 Types of Skeletal Muscle Fibers

1. Fast fibers- Contract very quickly
- Have large diameter, large glycogen reserves, few mitochondria
- Have strong contractions, fatigue quickly
2. Slow fibers-Are slow to contract, slow to fatigue
- Have small diameter, more mitochondria
- Have high oxygen supply
- Contain myoglobin (red pigment, binds oxygen)
3. Intermediate fibers-Are mid-sized
- Have low myoglobin
- Have more capillaries than fast fiber, slower to fatigue

Muscles and Fiber Types

- White muscle:
  - mostly fast fibers
  - pale (*e.g.*, chicken breast)
- Red muscle:
  - mostly slow fibers
  - dark (*e.g.*, chicken legs)
- Most human muscles:
  - mixed fibers
  - pink

Muscle Hypertrophy

- Muscle growth from heavy training:
  - increases diameter of muscle fibers
  - increases number of myofibrils
  - increases mitochondria, glycogen reserves

Muscle Atrophy

- Lack of muscle activity:
  - reduces muscle size, tone, and power

What is the difference between aerobic and anaerobic endurance, and their effects on muscular performance?

Physical Conditioning – Improves both power and endurance

Anaerobic Endurance

- Anaerobic activities (*e.g.*, 50-meter dash, weightlifting):
  - use fast fibers
  - fatigue quickly with strenuous activity
- Improved by:
  - frequent, brief, intensive workouts
  - hypertrophy

Aerobic Endurance

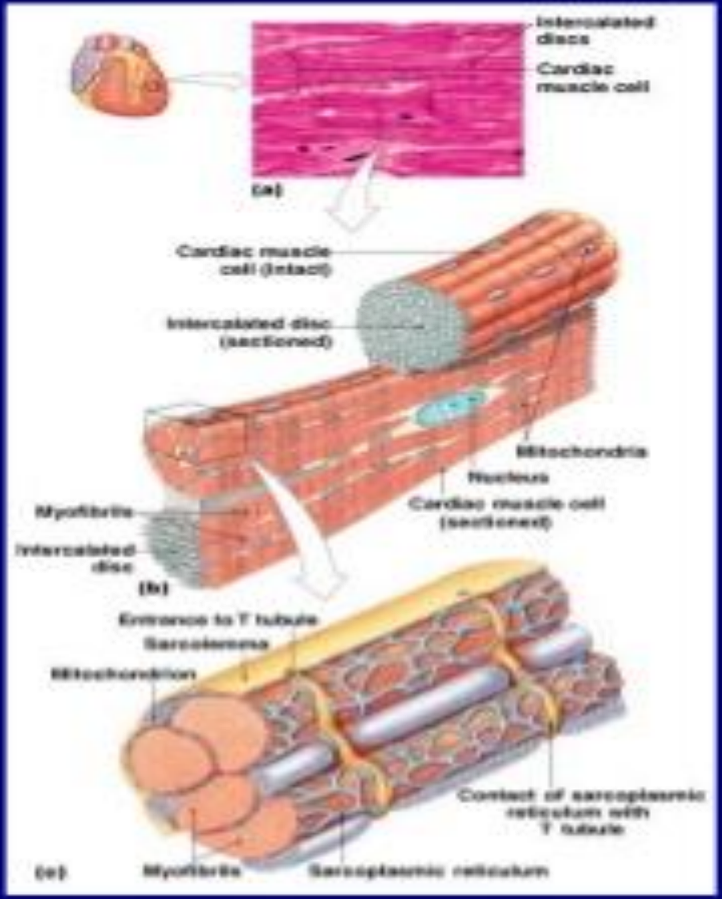
- Aerobic activities (prolonged activity):
  - supported by mitochondria
  - require oxygen and nutrients
- Improved by:
  - repetitive training (neural responses)
  - cardiovascular training

KEY CONCEPT

- What you don’t use, you loose
- Muscle tone indicates base activity in motor units of skeletal muscles
- Muscles become flaccid when inactive for days or weeks
- Muscle fibers break down proteins, become smaller and weaker
- With prolonged inactivity, fibrous tissue may replace muscle fibers

What are the structural and functional differences between skeletal muscle fibers and cardiac muscle cells?

Structure of Cardiac Tissue



- Cardiac muscle is striated, found only in the heart

Figure 10-22

7 Characteristics of Cardiocytes

- Unlike skeletal muscle, cardiac muscle cells (*cardiocytes*):
  - are small
  - have a single nucleus
  - have short, wide T tubules

7 Characteristics of Cardiocytes

- have no triads
- have SR with no terminal cisternae
- are aerobic (high in myoglobin, mitochondria)
- have intercalated discs

Intercalated Discs

- Are specialized contact points between cardiocytes
- Join cell membranes of adjacent cardiocytes (gap junctions, desmosomes)

Functions of Intercalated Discs

- Maintain structure
- Enhance molecular and electrical connections
- Conduct action potentials

Coordination of Cardiocytes

- Because intercalated discs link heart cells mechanically, chemically, and electrically, the heart functions like a single, fused mass of cells

4 Functions of Cardiac Tissue

1. Automaticity:
   - contraction without neural stimulation
   - controlled by pacemaker cells
2. Variable contraction tension:
   - controlled by nervous system
3. Extended contraction time
4. Prevention of wave summation and tetanic contractions by cell membranes

Role of Smooth Muscle in Body Systems

- Forms around other tissues
- In blood vessels:
  - regulates blood pressure and flow
- In reproductive and glandular systems:
  - produces movements
- In digestive and urinary systems:
  - forms sphincters
  - produces contractions
- In integumentary system:
  - *arrector pili* muscles cause goose bumps

What are the structural and functional differences between skeletal muscle fibers and smooth muscle cells?

Structure of Smooth Muscle

- Nonstriated tissue

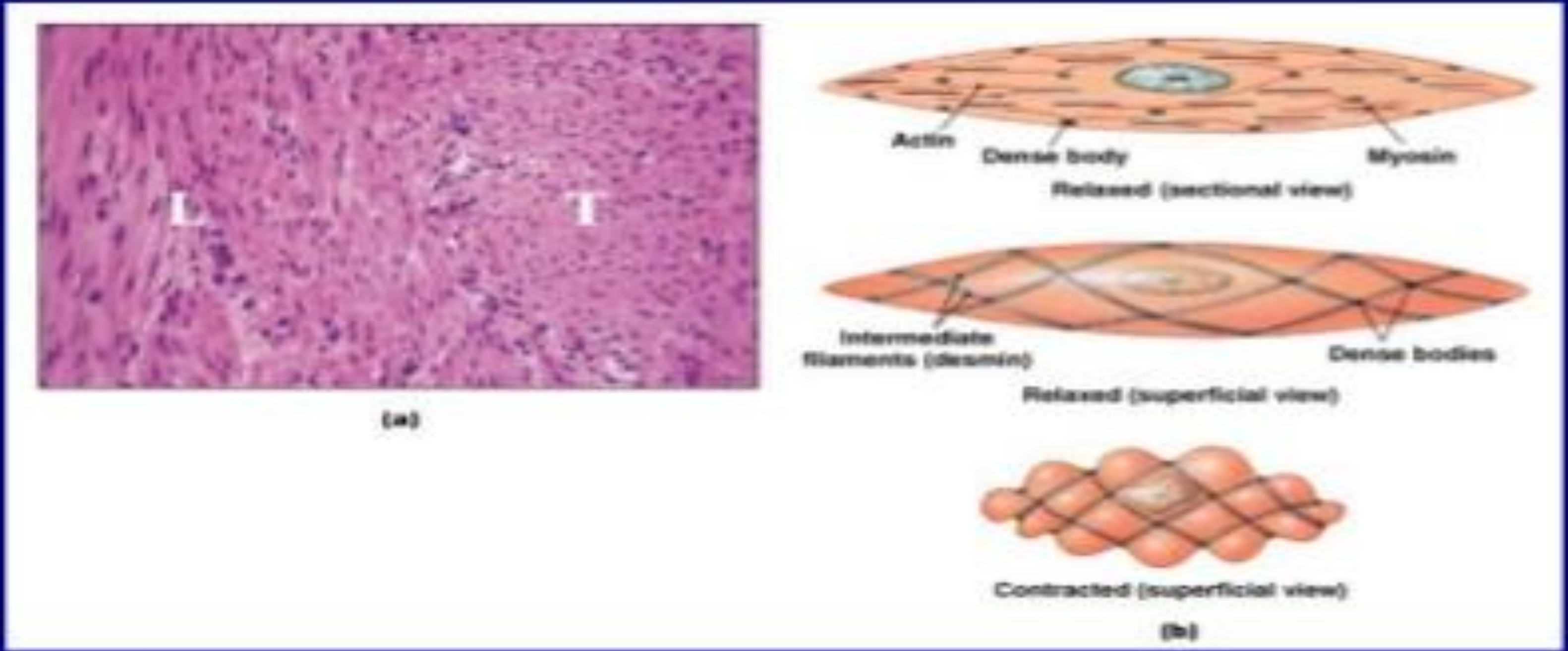


Figure 10-23

Comparing Smooth and Striated Muscle

- Different internal organization of actin and myosin
- Different functional characteristics

8 Characteristics of Smooth Muscle Cells

1. Long, slender, and spindle shaped
2. Have a single, central nucleus
3. Have no T tubules, myofibrils, or sarcomeres
4. Have no tendons or aponeuroses

8 Characteristics of Smooth Muscle Cells

5. Have scattered myosin fibers
6. Myosin fibers have more heads per thick filament
7. Have thin filaments attached to dense bodies
8. Dense bodies transmit contractions from cell to cell

Functional Characteristics of Smooth Muscle

1. Excitation-contraction coupling
2. Length-tension relationships
3. Control of contractions
4. Smooth muscle tone

Excitation–Contraction Coupling

- Free Ca^{2+} in cytoplasm *triggers* contraction
- Ca^{2+} binds with calmodulin:
  - in the sarcoplasm
  - activates myosin light chain kinase
- Enzyme breaks down ATP, *initiates* contraction

Length-Tension Relationships

- Thick and thin filaments are scattered
- Resting length not related to tension development
- Functions over a wide range of lengths (plasticity)

Control of Contractions

- Subdivisions:
  - multiunit smooth muscle cells:
    - connected to motor neurons
  - visceral smooth muscle cells:
    - not connected to motor neurons
    - rhythmic cycles of activity controlled by pacesetter cells

Smooth Muscle Tone

- Maintains normal levels of activity
- Modified by neural, hormonal, or chemical factors

Characteristics of Skeletal, Cardiac, and Smooth Muscle

TABLE 10–4 A Comparison of Skeletal, Cardiac, and Smooth Muscle Tissues

Property	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Fiber dimensions (diameter × length)	100 μm × up to 30 cm	10–20 μm × 50–100μm	5–10 μm × 30–200 μm
Nuclei	Multiple, near sarcolemma	Generally single, centrally located	Single, centrally located
Filament organization	In sarcomeres along myofibrils	In sarcomeres along myofibrils	Scattered throughout sarcoplasm
SR	Terminal cisternae in triads at zones of overlap	SR tubules contact T tubules at Z lines	Dispersed throughout sarcoplasm, no T tubules
Control mechanism	Neural, at single neuromuscular junction	Automaticity (pacemaker cells)	Automaticity (pacesetter cells), neural or hormonal control
Ca^{2+} source	Release from SR	Extracellular fluid and release from SR	Extracellular fluid and release from SR
Contraction	Rapid onset; may be tetanized; rapid fatigue	Slower onset; cannot be tetanized; resistant to fatigue	Slow onset; may be tetanized; resistant to fatigue
Energy source	Aerobic metabolism at moderate levels of activity; glycolysis	Aerobic metabolism, usually lipid or carbohydrate substrates	Primarily aerobic metabolism (anaerobic during peak activity)

Table 10-4

SUMMARY (1 of 3)

- 3 types of muscle tissue:
  - skeletal
  - cardiac
  - smooth
- Functions of skeletal muscles
- Structure of skeletal muscle cells:
  - endomysium
  - perimysium
  - epimysium
- Functional anatomy of skeletal muscle fiber:
  - actin and myosin

SUMMARY (2 of 3)

- Nervous control of skeletal muscle fibers:
  - neuromuscular junctions
  - action potentials
- Tension production in skeletal muscle fibers:
  - twitch, treppe, tetanus
- Tension production by skeletal muscles:
  - motor units and contractions
- Skeletal muscle activity and energy:
  - ATP and CP
  - aerobic and anaerobic energy

SUMMARY (3 of 3)

- Skeletal muscle fatigue and recovery
- 3 types of skeletal muscle fibers:
  - fast, slow, and intermediate
- Skeletal muscle performance:
  - white and red muscles
  - physical conditioning
- Structures and functions of:
  - cardiac muscle tissue
  - smooth muscle tissue

Structure, location , classification and function OF Nervous tissue.

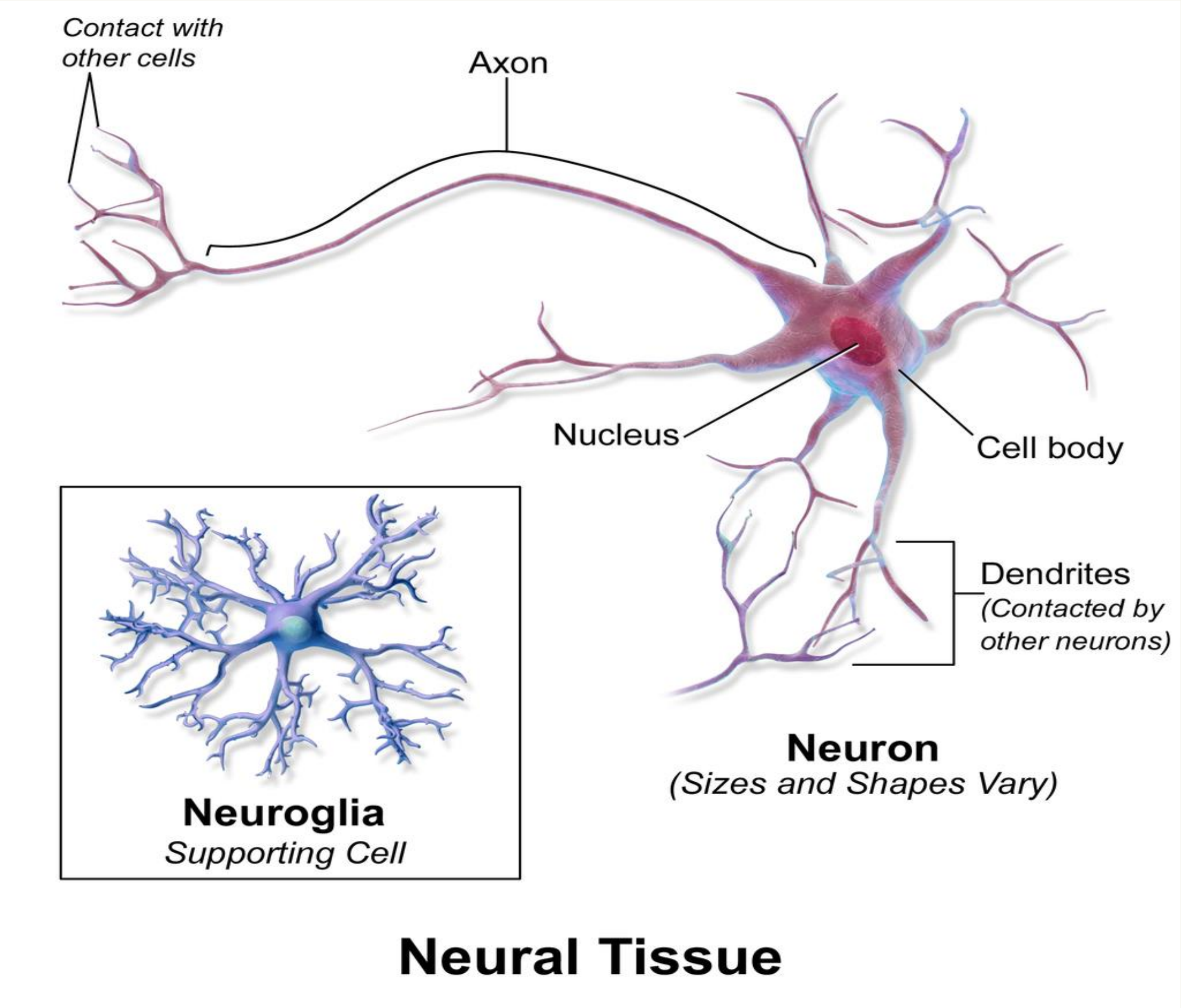
Nervous tissue, also called neural tissue, is the main tissue component of the nervous system. The nervous system regulates and controls bodily functions and activity and consists of two parts: the central nervous system (CNS) comprising the brain and spinal cord, and the peripheral nervous system (PNS) comprising the branching peripheral nerves.

It is composed of neurons, also known as nerve cells, which receive and transmit impulses, and neuroglia, also known as glial cells or glia, which assist the propagation of the nerve impulse as well as provide nutrients to the neurons.

Nervous tissue is made up of different types of neurons, all have an axon. An axon is the long stem-like part of the cell that sends action potentials to the next cell. Bundles of axons make up the nerves in the PNS and tracts in the CNS.

Functions of the nervous system are sensory input, integration, control of muscles and glands, homeostasis, and mental activity.

Neural Tissue



Structure

Nervous tissue is composed of neurons, also called nerve cells, and neuroglial cells. Four types of neuroglia found in the CNS are astrocytes, microglial cells, ependymal cells, and oligodendrocytes.

Two types of neuroglia found in the PNS are satellite cells and Schwann cells. In the central nervous system (CNS), the tissue types found are grey matter and white matter. The tissue is categorized by its neuronal and neuroglial components

Components

Neurons are cells with specialized features that allow them to receive and facilitate nerve impulses, or action potentials, across their membrane to the next neuron.

They possess a large cell body (soma), with cell projections called dendrites and an axon. Dendrites are thin, branching projections that receive electrochemical signaling (neurotransmitters) to create a change in voltage in the cell.

Axons are long projections that carry the action potential away from the cell body toward the next neuron. The bulb-like end of the axon, called the axon terminal, is separated from the dendrite of the following neuron by a small gap called a synaptic cleft.

When the action potential travels to the axon terminal, neurotransmitters are released across the synapse and bind to the post-synaptic receptors, continuing the nerve impulse

Neurons are classified both functionally and structurally.
Functional classification:

Sensory neurons (afferent): Relay sensory information in the form of an action potential (nerve impulse) from the PNS to the CNS

Motor neurons (efferent): Relay an action potential out of the CNS to the proper effector (muscles, glands)

Interneurons: Cells that form connections between neurons and whose processes are limited to a single local area in the brain or spinal cord

Structural classification:

Multipolar neurons: Have 3 or more processes coming off the soma (cell body). They are the major neuron type in the CNS and include interneurons and motor neurons.

Bipolar neurons: Sensory neurons that have two processes coming off the soma, one dendrite and one axon

Pseudounipolar neurons: Sensory neurons that have one process that splits into two branches, forming the axon and dendrite

Unipolar brush cells: Are excitatory glutamatergic interneurons that have a single short dendrite terminating in a brush-like tuft of dendrioles. These are found in the granular layer of the cerebellum.

Neuroglia encompasses the non-neural cells in nervous tissue that provide various crucial supportive functions for neurons. They are smaller than neurons, and vary in structure according to their function.

Neuroglial cells are classified as follows:

Microglial cells: Microglia are macrophage cells that make up the primary immune system for the CNS. They are the smallest neuroglial cell.

Astrocytes: Star-shaped macroglial cells with many processes found in the CNS. They are the most abundant cell type in the brain, and are intrinsic to a healthy CNS.

Oligodendrocytes: CNS cells with very few processes. They form myelin sheaths on the axons of a neuron, which are lipid-based insulation that increases the speed at which the action potential, can travel down the axon.

NG2 glia: CNS cells that are distinct from astrocytes, oligodendrocytes, and microglia, and serve as the developmental precursors of oligodendrocytes

Schwann cells: The PNS equivalent of oligodendrocytes, they help maintain axons and form myelin sheaths in the PNS.

Satellite glial cell: Line the surface of neuron cell bodies in ganglia (groups of nerve body cells bundled or connected together in the PNS)

Enteric glia: Found in the enteric nervous system, within the gastrointestinal trac

Classification of tissue
In the central nervous system:

Grey matter is composed of cell bodies, dendrites, unmyelinated axons, protoplasmic astrocytes (astrocyte subtype), satellite oligodendrocytes (non-myelinating oligodendrocyte subtype), microglia, and very few myelinated axons.

White matter is composed of myelinated axons, fibrous astrocytes, myelinating oligodendrocytes, and microglia.

In the peripheral nervous system:

Ganglion tissue is composed of cell bodies, dendrites, and satellite glial cells.
Nerves are composed of myelinated and unmyelinated axons, Schwann cells surrounded by connective tissue.

The three layers of connective tissue surrounding each nerve are:

Endoneurium. Each nerve axon, or fiber is surrounded by the endoneurium, which is also called the endoneurial tube, channel or sheath. This is a thin, delicate, protective layer of connective tissue.

Perineurium. Each nerve fascicle containing one or more axons, is enclosed by the perineurium, a connective tissue having a lamellar arrangement in seven or eight concentric layers. This plays a very important role in the protection and support of the nerve fibers and also serves to prevent the passage of large molecules from the epineurium into a fascicle.

Epineurium. The epineurium is the outermost layer of dense connective tissue enclosing the (peripheral) nerve.

Function

Myelinated axons conduct impulses faster than unmyelinated axons.

The function of nervous tissue is to form the communication network of the nervous system by conducting electric signals across tissue.

In the CNS, grey matter, which contains the synapses, is important for information processing. White matter, containing myelinated axons, connects and facilitates nerve impulse between grey matter areas in the CNS. In the PNS, the ganglion tissue, containing the cell bodies and dendrites, contain relay points for nerve tissue impulses.

The nerve tissue, containing myelinated axons bundles, carry action potential nerve impulses.

THANK YOU