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Part Two:

Epithelial & Connective Tissues

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1. Epithelial Tissue

Epithelial Membrane

- Epithelia covering external surfaces or lining internal surfaces.
- Form interface between compartments.

Glands

- Modified for secretion.
- Form invaginated epithelial cells

1.1 Characteristics:

- Tightly bound together by junctional complex, with very little extracellular matrix and very little intracellular space (between cells).
- Separated from connective tissue by basal lamina (made by epithelial cells).
 - Hemidesmosome: Type of junctions to fix (like glue) the cell of the underline lamina to the C.T.
- Avascular (no blood vessels).
 - Nourishment & getting O₂ via diffusion from CT (connective tissue) through basal lamina.
- Derived from all three embryological germ layers: Ectoderm, endoderm and mesoderm.
- Constant cell renewal for a particular epithelium. (It has a specific lifespan).

1.2 Functions:

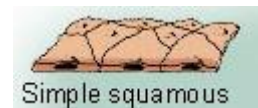
- 1) Protection.
- 2) Transcellular transport.
- 3) Secretion of mucus, hormones and enzymes.
- 4) Absorption.
- 5) Detection of sensation (as taste buds and retina).
- 6) Selective permeability.

1.3 Classifications:

- According to shape:
 - Squamous.
 - Columnar.
 - Cuboidal.
- According to layers:
 - Simple.
 - Stratified.

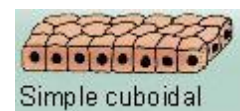
1.3.1 Simple Squamous Epithelium:

- Flattened polygonal cells with central flat nuclei.
- Found in: Pulmonary alveoli, loop of Henle (kidney), endothelium of blood vessels, pleura and peritoneal cavities.



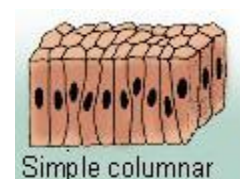
1.3.2 Simple Cuboidal Epithelium:

- Cuboidal polygonal cells with central round nuclei.
- Found in: Ducts of many glands, covering of the ovary, follicular cells of thyroid follicles and some kidney tubules.



1.3.3 Simple Columnar Epithelium:

- Tall rectangular cells with oval nuclei usually at the basal half.
- Found in: Lining of stomach, gall bladder and large ducts of glands.
 - Some have cilia, e.g. uterus, oviducts, small bronchi (lungs).
 - Some exhibit goblet cells or microvilli, e.g. intestines.

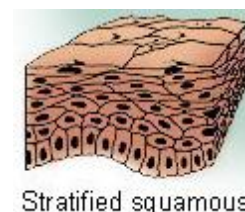


1.3.4 Pseudostratified Columnar Epithelium:

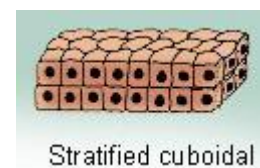
- Single layered cells that appear to be stratified. Every cell touches the basal lamina but not all reach the surface. Nuclei are located at different layers
- Cells that don't reach the surface have a broad base and narrow at the apical end. While those which reach the surface have narrow base and broad at the apical end.
- Commonly have cilia on the apical surface.
- Found in: Male urethra, epididymis.
 - Has goblet cells (that release mucus), **e.g.** respiratory tract epithelium.
 - No goblet cells **e.g.** auditory tube and lacrimal sac.

**1.3.5 Stratified Squamous Epithelium:**

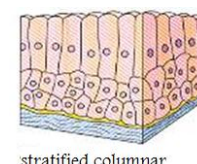
- Most basal layer rests on basal lamina and it consists of cuboidal cells.
- The intermediate layers are polyhedral or polymorphous.
- The most superficial layer is formed of flat squamous cells.
 - 1) Non-keratinized: Superficial layer not covered by keratin (dead tissue). **e.g.** lining of mouth, oral pharynx, esophagus, true vocal cords and vagina.
 - 2) Keratinized: Superficial layer covered by keratin. **e.g.** epidermis of skin especially in soles and palms.
- Keratin is found only in stratified squamous epithelium.
- Stratified epithelium dose not have goblet cells, cilia or microvilli.

**1.3.6 Stratified Cuboidal Epithelium:**

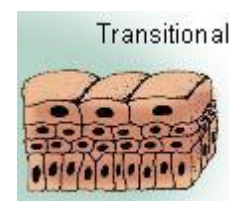
- Two layers of cuboidal cells.
- Most basal layer rests on basal lamina.
- **e.g.** ducts of sweat glands.
- Stratified epithelium dose not have goblet cells, cilia or microvilli.

**1.3.7 Stratified Columnar Epithelium:**

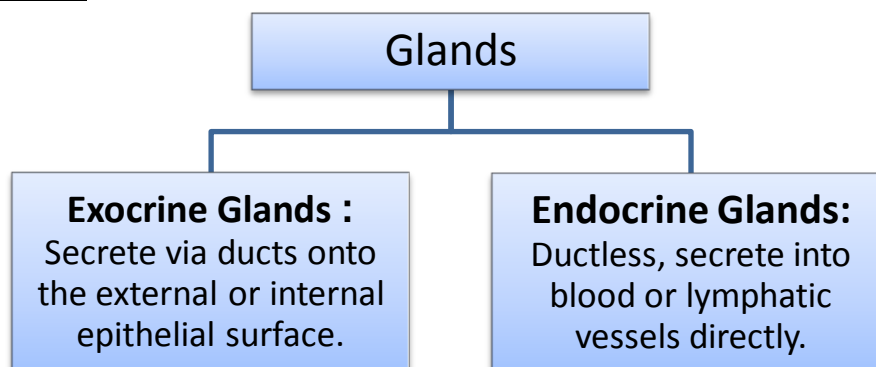
- Superficial layer composed of columnar cells.
- Basal cells are polyhedral to cuboidal.
- **e.g.** conjunctiva of the eye, large excretory ducts and regions of male urethra.
- Stratified epithelium dose not have goblet cells, cilia or microvilli.

**1.3.8 Transitional Epithelium:**

- Many (3-6) layers of cells.
- Basal layer: Low columnar or cuboidal.
- Superficial layer: Large dome-shaped binucleated cells.
- **e.g.** bladder.
- In full bladder, the dome-shaped cells become flattened and the epithelium becomes thinner.



1.4 Glands:



Consists of:

1. Parenchyma: Formed of secretory units and ducts.
2. Stroma: Elements of the connective tissue that invade and support the parenchyma (formed of capsule, septa and supporting background).

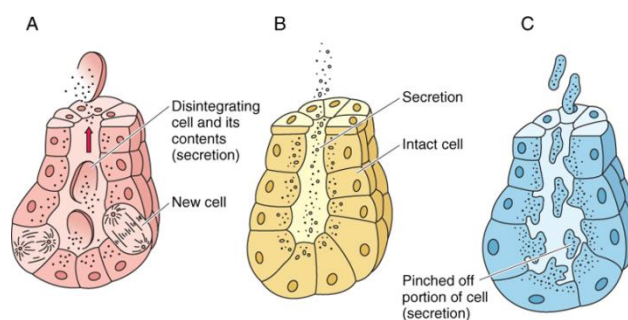
1.4.1 Classification of Exocrine Glands:

A. According to number of cells:

1. Unicellular (Goblet cells).
2. Multicellular.

B. According to mechanism of release of secretion:

1. **Holocrine**: Complete destruction of secretory cell. They die and become products, **e.g.** sebaceous glands.
2. **Merocrine**: Excretion via exocytosis, with out loss of any part, **e.g.** salivary glands.
3. **Apocrine**: Apical part (tip) of the gland is lost with the secretion, **e.g.** mammary glands.



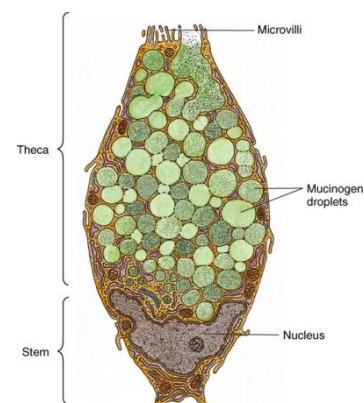
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C. According to nature of secretion:

1. **Mucous glands**: Mucous acini, **e.g.** minor salivary glands of tongue and palate.
 - Secrete mucinogens (large glycoproteins that swell to become mucin)
 - Mucin is a thick lubricant which is a major component of mucus.
 - Small, flattened, basal nuclei; few mitochondria; less RER.
 - The apical part is rich in secretory carbohydrate granules.
 - Acinus (pl. acini) is the termination of a gland, where secretion is produced.
2. **Serous glands**: Serous acini **e.g.** pancreas.
 - Pyramidal with large, rounded, basal nuclei.
 - ER and golgi complex has numerous basal mitochondria and abundant apical secretory granules.
 - Secrete an enzyme-rich watery fluid.
3. **Mixed (mucoserous) glands**: Mucous acini and serous acini.
 - Some mucous acini possess serous semilunes, a group of cells that secrete a serous fluid.
 - **e.g.** submandibular and sublingual glands.

1.4.2 Goblet Cells (Unicellular glands):

- Mucous glands that are dispersed individually in the epithelia lining the digestive track and portions of the respiratory tract.
- Thin basal region lies on basal lamina. Apical portion, theca, faces the lumen of the tract.



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1.4.3 Multicellular Exocrine Glands:

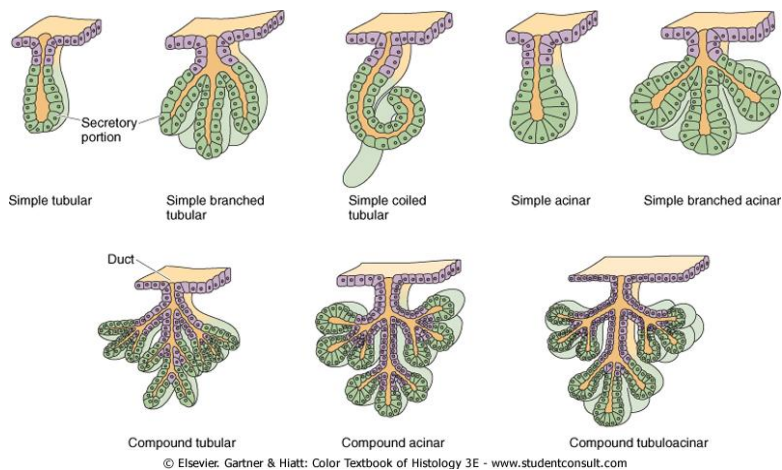
- A group of secretory cells and ducts surrounded by a collagenous connective tissue capsule, which sends septae (strands of connective tissue) into the gland, subdividing it into lobes and lobules.
- Classified according to the duct shape into:
 - Simple: Non-branching ducts.
 - Compound: Branching ducts.
- Classified according to the morphology of secretory units into:
 - Tubular.
 - Acinar (alveolar).
 - Tubuloalveolar.

1.4.4 Endocrine Glands:

- Secrete hormones that pass directly into the blood or lymph without ducts.
- Hormones may be polypeptides e.g. anterior pituitary, proteins e.g. thyroid or steroid e.g. adrenal hormones.
- Hormones are stored within the endocrine cells or the lumen of the follicles.
- Their cells are arranged either in cords as in pituitary gland or as follicles as in thyroid glands.
- Diffuse neuroendocrine system (DNES), are widespread throughout the digestive tract and respiratory system.

1.4.5 Myoepithelial cells:

- They share the basal lamina of acinar cells and small ducts of many multicellular exocrine glands such as sweat and major salivary glands.
- They are epithelial in origin, but have some characteristics of smooth muscle cells (contractility).
- They have small nuclei and fibrillar cytoplasm radiating from the body wrapping around the acini and small ducts.
- Help squeezing and expressing secretions from the acini and small ducts.



2. Basement Membrane:

- Cellular region that interface between epithelial and connective tissue.
- Visible by L/M.
- Has two constituents:
 1. Basal Lamina: Elaborated by epithelial cells.
 2. Lamina Reticularis: Can be seen by L/M. Manufactured by cells of the connective tissue.
- Basal surface specializations include:
 - Basal Lamina.
 - Plasma membrane enfolding.
 - Hemidesmosomes.

2.1 Basal Lamina:

- Only visible by E/M (20-100 nm thick)
- Extracellular supporting structure.
- Located at the boundary between the epithelium and the underlying connective tissue.
- Has two regions:
 1. Lamina Lucida (lamina rara).
 - Electron lucent region beneath the epithelium.
 - Consist of extracellular glycoproteins, laminin and entactin.
 2. Lamina Densa:
 - Electron dense region.
 - Meshwork of type IV collagen.

2.1.1 Plasma membrane enfoldings:

- Basal surface possesses finger-like enfoldings of the basal plasma membrane.
- Function: Increase the surface area.
- Formed by the basal cytoplasm and mitochondria.
- Involved in ion transport and are found in striated ducts of salivary glands (visible by L/M)

2.1.2 Hemidesmosomes:

- Half desmosomes.
- Function: attach basal cell membrane to basal lamina.
- Attachment plaque present on the cytoplasmic aspect of the plasma membrane.
- Keratin tonofilaments insert into these plaques.

2.1.3 External lamina:

- Similar to basement membrane and surrounds smooth muscle, skeletal muscle, adipocytes and Schwann cells.

2.2 Lamina reticularis:

- Composed of type I & III collagen that manufacture by fibroblasts of underlying CT.
- Thick in skin and very thin around alveoli.

Polarity and cell-surface specialization:

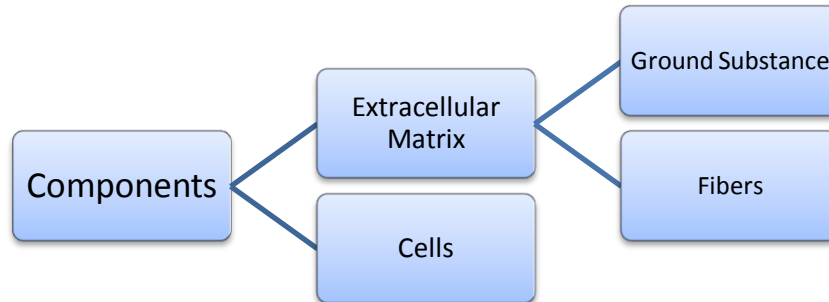
- Apical domain, e.g. microvilli, cilia, stereocilia and flagella.
- Basolateral domain:
 - a. Lateral plasma membrane specializations, as junctional complexes and intercellular interdigitations.
 - b. Basal plasma membrane specializations, as enfolding and hemidesmosomes.

3. Connective Tissue:

- It is a basic type of tissue which provides structural and metabolic support for tissues and organs.

3.1 Characteristics:

- Vascular, except dense C.T.
- Cells are widely separated.
- Few cells with abundant extracellular matrix.
- Originates from mesenchyme (an embryonic tissue) which develops mainly from mesoderm.



3.2 Functions:

1. Structural Support (Physical and mechanical).
2. Medium for exchange.
3. Defense & projection of the body.
4. Storage of fat.

3.3 Extracellular Matrix:

3.3.1 Ground substance:

- Hydrated, amorphous material.
- Composed of :
 1. Glycosaminoglycans (GAGs):
 - -ve charged rod-shaped long unbranched polymers of disaccharides.
 - Have the capability of binding large quantities of water.
 - Can be sulfated or non-sulfated, **e.g.** hyaluronic.
 2. Proetoglycans:
 - Protein core binds to GAGs covalently to form macromolecule.
 - GAGs represent 80-90%, **e.g.** heparan, sulfate & heparin.
 3. Adhesive Glycoproteins
 - Large macromolecules.
 - Attach various components of the extracellular matrix to each other.
 - Attach components with integrins of the cell membrane that facilitate the attachment of cells to the extracellular matrix.
 - **e.g.** Fibronectin, laminin.

3.3.2 Fibers (Collagen & Elastin):

3.3.2.1 Collagen:

- Inelastic and possesses a great tensile strength, unbranched.
- Composed of tropocollagen.
- Acidophilic.
- Under EM the fibers show cross-banding at regular intervals.

Synthesis:

- By fibroblast.
- Preprocollagen → Procollagen → Tropocollagen → Fibrils.
- Fibrillar collagens include type I, II, III, V and VII.
- Fibrillar structure is absent in type IV collagen.

Types:

- Type I:
 - Acidophilic thick fibers, most common, **e.g.** bone.
- Type II:
 - Forms slender fibers, **e.g.** Hyaline & elastic cartilage.
- Type III:
 - Known as reticular fibers, **e.g.** red bone marrow.
 - Stained with silver or PAS.
- Type IV:
 - Meshwork procollagen, **e.g.** lamina densa of the basal lamina.
- Type V:
 - Forms thin fibers associate with type I, **e.g.** placenta.
- Type VII:
 - Attach lamina to lamina reticularis.

3.3.2.2 Elastin:

- Composed of elastin and microfibrils of fibrillin.
- Highly elastic, branching.
- Amorphous material.
- Weak acidophilic
- May form coarser bundles, **e.g.** ligaments, or fenestrated sheets, **e.g.** aorta.
- Formed by fibroblasts and smooth muscle.
- Origin:
 - Proelastin from fibroblast (or from smooth muscle cells of blood vessels)
 - Microfibrils are composed of fibrillin (glycoprotein) which is formed first.

Cellular Components:

- **Fixed cells:** Cell remain in place within the connective tissue (long lived):
 1. Fibroblasts.
 2. Adipose cells.
 3. Pericytes.
 4. Mast cells.
 5. Macrophages.
- **Transient cells:** Originate from bone marrow and circulate the blood stream:
 1. Plasma cells.
 2. Leucocytes.
 3. Macrophages.

3.4 Fixed Cells:

3.4.1 Fibroblasts:

- Most abundant in the connective tissue.
- Originate from undifferentiated mesenchymal cells.
- Synthesize the extracellular matrix of the connective tissue.
- Helps in healing of wounds.
- Can differentiate into osteoblasts, chondrocytes, fat cells.
- May undergo cell division.
- May occur in active or inactive state.

3.4.1.1 Active Fibroblasts:

- Under L/M:
 - Basophilic.
 - Elongated, fusiform cells.
 - Nucleus: dark-stained, large, granular, ovoid.
- Under E/M:
 - Prominent golgi apparatus.
 - Abundant RER.

3.4.1.2 Inactive Fibrocytes:

- Under L/M:
 - Acidophilic.
 - Smaller, more ovoid cell.
 - Small nucleus.
- Under E/M:
 - Sparse (scattered) RER.
 - Abundant free ribosomes.



Fibroblast

Myofibroblast:

- Similar to fibroblast by L/M.
- Have bundles of actin.
- Basal lamina is absent.
- Abundant in areas undergoing wound healing.

3.4.2 Adipose Cells:

- Derived from undifferentiated mesenchymal cells.
- Do not undergo cell division.
- Function: Synthesize and store triglycerides.
- They are two types:

3.4.2.1 Unilocular fat cells:

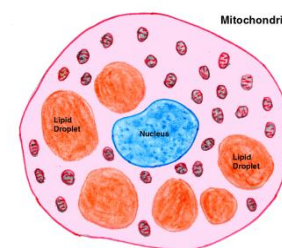
- Under L/M:
 - Large, polyhedral cells (50-120).
 - Store fat in the form of single droplet.
 - Cytoplasm and nucleus are peripheral (signet ring).
- Under E/M:
 - Small golgi apparatus, thinly spread RER, abundance of free ribosomes, SER.
 - The fat droplet is not bounded by membrane.
 - Each cell is surrounded by basal lamina-like substance & supported by reticular fibers.



Adipocyte

3.4.2.2 Multilocular fat cells:

- Form brown adipose tissue.
- Under L/M:
 - Smaller than unilocular, and more polygonal.
 - Fat is stored in several small droplets.
 - Spherical, central nucleus.
- Under E/M:
 - They have SER, but lack RER.
 - More mitochondria with abundant long cristea.
 - Fewer free ribosomes.
 - Receive direct sympathetic innervations.
- Site: Human embryo and new born.
- Function: Production of heat.

**3.4.3 Pericytes:**

- Derived from undifferentiated mesenchymal cells.
- Surround endothelial cells of capillaries and small venules.
- Surrounded by its basal lamina.
- May differentiate into other cells.
- Have long primary and secondary processes.

3.4.4 Mast Cells:

- Largest of the fixed cells.
- Oval cells.
- Nucleus: center, spherical.
- Can divide.
- Derived from precursor in the bone marrow.
- Numerous, membrane bounded granules in the cytoplasm.
- Contain heparin and histamine.
- They are concentrated along small blood vessels, subepithelial connective tissue of the respiratory system.



Mast cell

3.4.5 Macrophages:

- Fixed or free.
- Under L/M:
 - Basophilic.
 - Have many vacuoles & small dense granules.
 - Nucleus: Small, eccentric, dark, and kidney-shaped.
 - Nucleolus: Usually don't appear.
 - Irregular outline, have filopodia (projections from the cell) that fold in active cells.
- Under E/M:
 - Well-developed golgi apparatus.
 - Prominent of RER.
 - Prominent phagosomes (phagocytic vacuoles).
 - Abundance of lysosomes.
- Functions:
 - Phagocytosis.
 - Antigen processing and presentation.
 - Production of cytokines and chemotactic factors.
- Origin: Monocytes.
- They can divide.
- They have certain regions in the body **e.g.** kupffer cells of the liver, dust cells of the lung, langerhans cells of the skin.
- Life span: ~ 2 months.

3.5 Transient Cells:

3.5.1 Plasma Cells:

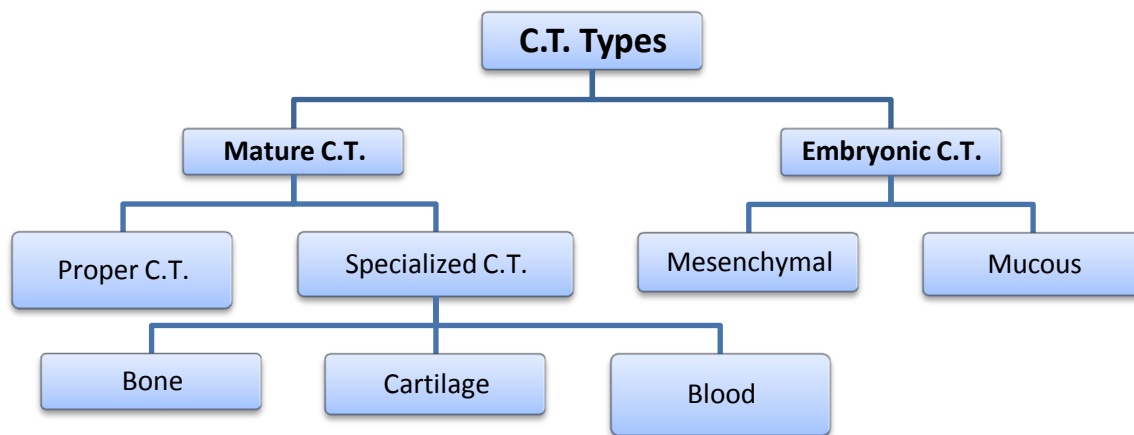
- Under L/M:
 - Basophilic.
 - Negative golgi apparatus.
 - Nucleus: Spherical, eccentric & clock-face appearance.
 - Large (20 um), ovoid cells.
- Under E/M:
 - Abundant RER.
 - Well-developed golgi complex.
 - Few mitochondria.
- Function: Synthesis & release antibodies.
- Derived from B lymphocytes.
- Nucleus: Possess heterochromatin radiating out of the center it gives (clock-face) (spoken) appearance.
- Pair of centriols.



Plasma cell

3.5.2 Leukocytes:

- White blood cells that circulate in the blood stream.
- They divide to:
 1. Eosinophils.
 2. Basophils.
 3. Lymphocytes.
 4. Monocytes.
 5. Neutrophil.



3.6 Embryonic C.T.:

3.6.1 Mesenchymal C.T.:

- Present in embryo.
- Under L/M:
 1. Mesenchymal cells:
 - Basophilic cytoplasm with small processes.
 - Nucleus is oval with prominent nucleolus.
 2. Ground substance:
 - Gel-like & amorphous.
 3. Scattered reticular fibers.
 - Prominent nucleoli.

3.6.2 Mucous C.T.:

- Under L/M:
 - Ground substance (Hyaluronic Acid).
 - Few fibers (Type I & III collagen fibers).
 - Fibroblasts.
- Found in:
 - Umbilical cord.
 - Subdermal C.T. of the embryo.
 - Pulp of young teeth.
- Known as Wharton's jelly.

3.7 Mature C.T.:

3.7.1 C.T Proper:

3.7.1.1 Loose (Areolar) C.T.:

- Sites:
 - Papillary layer of the dermis.
 - Hypodermis.
 - Serosa (peritoneum, pleura).
 - Lamina propria.
 - Tunica Adventitia of blood cells.
- Under L/M:
 - Contain all the main components C.T.P., (with no predominant element).
 - Fibroblasts & macrophages are the most numerous cells.
 - Loose C.T of mucous membranes (as in the alimentary canal) is called the lamina propria.
 - Abundant ground substance and tissue fluid housing the fixed cells and some undifferentiated cells.
 - Scattered collagen, reticular, elastic fibers.

3.7.1.2 Dense C.T.:

- Under L/M:

- Fewer cells (few fibroblasts), more fibers.
- If collagen fibers are arranged randomly, it's called dense irregular C.T..
- If it's arranged parallel to each other it's called dense regular C.T and can be collagenous or elastic.

- Types:

- 1) Dense Irregular C.T.:

- Randomly arranged collagen fibers which form a meshwork that resists stress.
- Few ground substances.
- Fibroblasts scattering between collagen fibers.
- **e.g.** the dermis of the skin, capsules of testes, ovary, kidney, nerve sheath.

- 2) Dense regular collagenous C.T.:

- Composed of collagen bundles packed parallel to each other.
- Few ground substances and fibroblasts between collagen bundles.
- **e.g.** tendons, ligaments, aponeuroses.

- 3) Dense regular elastic C.T.:

- Coarse branching elastic fibers with few collagen fibers.
- Fibroblasts are scattered throughout the interstitial space.
- Elastic fibers form thin sheets or fenestrated (having windows) membranes, as in large blood vessels, ligamenta flava of the vertebral column.

3.7.1.3 Reticular Tissue:

- Under L/M:

- Type III collagen is the major component
- Collagen forms a mesh-like network interspersed with Fibroblasts and macrophages.

- It forms the architectural framework of liver sinusoids, bone marrow, lymph nodes, spleen and smooth muscle.

3.7.1.4 Adipose Tissue:

- Classified into two types:

- 1. White (unilocular) adipose tissue:**

- Under L/M:

- Formed of unilocular adipose cells.
- Heavily supplied with blood vessels.

- Function:

- Synthesis, Storage & release of fat
- Thermal insulator
- Shock absorber

- Sites:

- Subcutaneous layer (especially in buttock and hips).
- Abdominal wall.
- Female breast.
- Around the kidney.

- It appears only after birth.

- 2. Brown (multilocular) adipose tissue:**

- Under L/M:

- Formed of multilocular adipose cells.
- Heavily supplied with blood vessels. (that's why brown).
- Numerous mitochondria. (that's why brown as well).

- Function:

- Synthesis, Storage & release of fat.
- Thermal insulator.
- Shock absorber.
- Present in infants of most mammals.