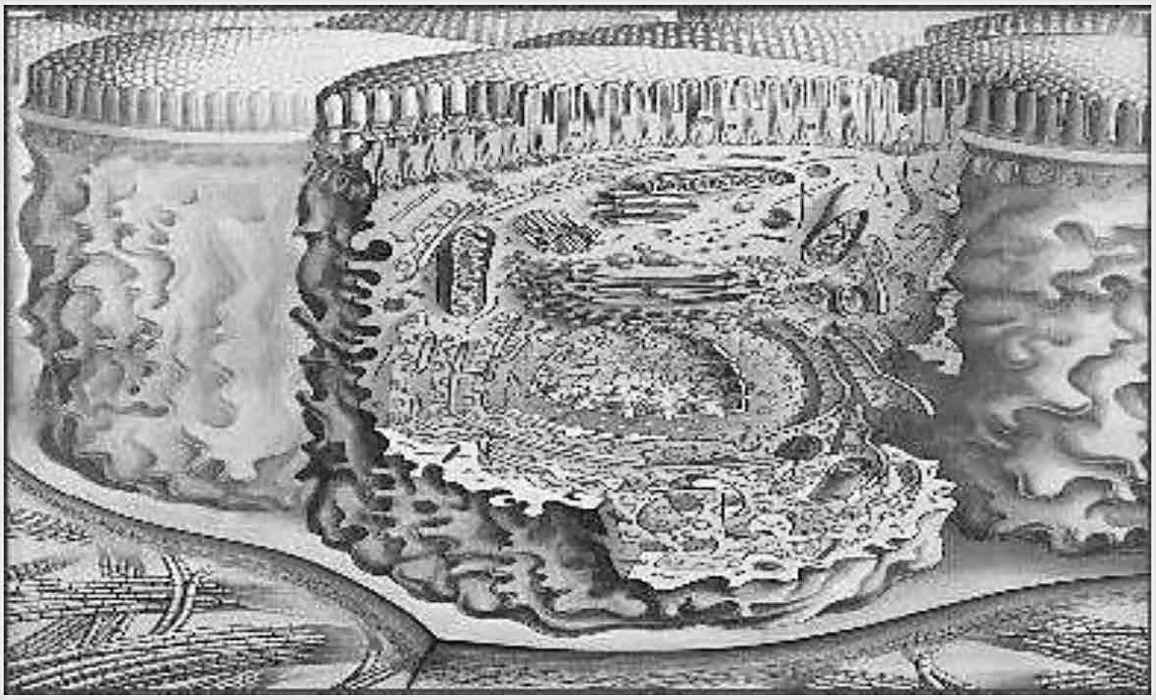
Faculty of Medicine
Menoufia University

Introduction to histology

For Pharmacy Students



First year

By

Staff Members of Histology and Cell Biology

-Contents: Page

I-Introduction: it is a science that studies the structure of the cells, tissues and organs.

- **Microscopy**: it is the tool by which we can study histology of the tissue.

Methods of studying Histology

1- Microtechniques

2-Cell culture

3-Electron microscopy

4- Histochemical & immunohistochemical techniques

5-Radio-autography

6- Differential centrifugation

Microtechniques

-**Definition**: different techniques for preparation of tissues to be examined under the microscope.

-**Methods**:

A- Freezing method (the most rapid method).

B- Paraffin method (the most common method).

C- Cellodin method (the most ideal method).

A-paraffin Method: Its steps are:

1- **Fixation** of tissue in 10% formol saline(for 3-5 days).

2- **Washing** in tap water **to** remove the fixative (for 2 minutes).

3- **Dehydration** in ascending grades of ethanol (50%, 70% and 90% over night), then in absolute alcohol (100%) for 3 hours.

4- **Clearing** in xylol or benzene **to** remove the alcohol from the tissue and to make the tissue miscible with paraffin in the next step.

5-**Impregnation** (in soft paraffin at 50^0C), this is done in an oven (for 20 minutes to 2 hours) according to the nature of the tissue, for infiltration of the soft paraffin in the tissue.

6-**Embedding (**in hard paraffin at 55°C), in an oven.

7-**Cutting** by microtom at a thickness of 5-7 um to obtain thin sections.

8-**Mounting** the tissues on slides.

9- **Staining** the tissues' slides.

Staining of paraffin sections with Hx&E

1-De-paraffinise the section (in xylol) for 2 minutes to remove the paraffin.

2-Hydrate the tissue (in descending grades of alcohol, 100, 90, 70, and 50%, 1 minute/ each).

3-Rinse the tissue in distilled water for 1 minute.

4- Stain in **hematoxylin** (Hx.) for 3-5 minutes.

5-Bluing in tap water for 5 minutes.

6-Stain the tissues with **eosin** for 1 minute.

7-Rinse in distilled H2O for 2 minutes

8-Dehydrate in alcohol (50, 70, 90, and 100%, 1 minute/ each)

9-Clear in xylol for 2 minutes.

10-Mount with canda balsam and cover with cover slide.

11- After the tissue dried, it is examined under the microscope.

Common Stains in light Microscopy

1-Bbasophilic stain(Haemotoxyline).

2-Acidophilic stain (eosin).

2-Neutral Stain (as Leishman stain for blood film).

3-Trichrome Stain (for collagen fibers).

4-Osmic acid stain (for lipids and myelin sheath).

5- Sudan III stain (for lipids).

6- Vital stain (for phagocytic cell as trypan blue).

7- Supra-vital stain (brillant cresyl blue stain for reticulocyte of blood).

8-Metachromatic stain (toluidine blue for mast cell).

9- Silver stain (reticular tissue& nerve fiber).

10-Silver impregination (for Golgi complex).

11- Histochemical methods for enzymes .

12-Immunohistochemical methods for detection of different antigens.

II-Cytology:

Definition: It is the study of histological structure of the cell.

The cell is formed of:

-***Cytoplasm***

-***Nucleus***

The cytoplasm: It is formed of:

1- cell organelles (membranous &non-membranous).

2- cell inclusions.

3- cytoplasmic matrix.

Cell Organelles

A-Membranous cell organelles

1-cell membrane 2-mitochondria 3- Endoplasmic reticulum

4-Golgi Apparatus 5-Lysosome 6-Peroxisomes

7-Coated vesicles 8-Endosomes 9- Annulate Lamellae

B-Non-membranous cell organelles

1- Ribosomes.

2- Microtubules (Centrioles & cilia &flagella).

3- Cytoplasmic filaments

2-Cell Inclusions

1- Stored foods (glycogen & fats).

2- Pigments : A- exogenous pigments. B-endogenous pigments

3-cytoplasmic matrix:

-It is a solution of proteins, fat, carbohydrate, enzymes and minerals present in cytoplasm.

1- Cell membrane:

- It is one of membranous cell organelles.

-It is not seen by LlM.

-By ElM, it has **tri-lamellar** appearance. It is formed of lipids (phospholipids & cholestrol), proteins and carbohydrates.

1- **Lipids**: each phospholipid molecule is formed of:

A-Hydrophilic charged heads

B- Hydrophobic non charged tails

2- **Proteins** are of 2 groups; a- **Integral** (intrinsic, trans-membrane) and b- **peripheral** (extrinsic) that is attached to the cytoplasmic surface.

3-**Carbohydrates** are linked to the surface protein to form **glycoproteins** and linked to the surface lipids to form **glycolipids**, both forming the cell coat (**glycocalyx**) which is rich in cell receptors that perform different functions.

-The **cholesterol** molecules are attached to the inner aspect of the cell membrane.

Function of cell membrane

1- Simple passive diffusion (as ions) which needs no energy for transport.

2- Active diffusion (needs energy which is supplied by ATP).

3- Selective diffusion (by receptors).

4- Transport of solid materials by **phagocytosis**.

5- Transport of liquid materials by **pinocytosis**.

6- Release of residual materials by **exoctytosis**.

7- Sodium- Potassium pump (more K+ inside and more Na+ outside the cell membrane).

2-Mitochondria

-It is one of membranous Cell organelles.

-By LlM, it appears as rods, filaments or granules.

-By ElM, it appears as oval structure having double membranes; the **outer** is smooth and the **inner** is folded forming cristae.

-It is filled with mitochondrial **matrix**, formed of proteins, fat, carbohydrate, vitamens, respiratory enzymes, DNA, RNA, Ca+, Mg+, and zink granules.

-It stains **blue** with iron hematoxylin and **green** with Janus green.

-its number increases or decreases according the function of the cell (e.g. liver cell has 2000 mitochondria).

-It is motile, contractile structure and **can divide** (it has DNA).

Function: -

-It is the respiratory apparatus of the cell, acts as power house for the cell.

-Their enzymes perform all cellular oxidative phosphorylation processes.

- They regulate the metabolism of calcium and other minerals.

- Self replication by simple fission (due to presence of mitochondrial DNA).

3-Endoplasmic Reticulum

-It is of 2 types; Rough ER (rER) and Smooth ER (sER).

-RER:

-it is formed of communicating flat tubules covered with ribosomes.

-It gives the cytoplasm its basophilic appearance.

-It is found more in protein secreting cell as **pancreatic** cell and **fibroblast**.

-Its function is protein secretion (by ribosomes), storing and delivery of proteins to the Golgi complex..

-SER:

-It is formed of communicating flat tubules with smooth surface (due to lack of ribosomes).

-It is found more in lipid secreting cells as **liver** and **endocrine** cells.

-Its **function** is:

- Lipid and fatty acid synthesis.

-Glycogen storage,.

-Regulate calcium distribution during muscle contraction.

4- Golgi Apparatus:

-It is one of membranous Cell organelles.

-By **L/M**: it appears as network beside the nucleus in secretory cell and around the nucleus in nerve cell (it is stained by **silver** stain).

-By **ElM**: it appears as **3** units; flat saccules, large macro-vesicles and small micro-vesicles.

-Its **function** is:

1- Condensation and packing of secretory products of the cell.

2- Addition of Carbohydrate to certain products.

3- Addition of sulphates to cell products.

4- Share in cell membrane formation.

5- Share in lysosome formation from endoplasmic reticulum.

5- Lysosomes:

-They are one of membranous cell organelles .

-By L/M: they appear as dark granules with **acid phosphatase** stain, or by **fluorescence** microscope.

-By ElM: they appear as 2 types; **primary** (homogenous rounded small bodies) and **secondary** (heterogeneous small bodies).

-They are rich in hydrolytic enzymes as lipase, proteases and acid phosphatases.

Origin: they are formed and modified in rER and Golgi apparatus.

-**Fate**: remain as **primary** lysosome or fuse with **phagocytic** bodies to change into **secondary** lysosomes (**phagosome**, **multivesicular** bodies, **autophagic** vacuoles or **residual** bodies).

Function:

1- Digestion of phagocytosed substances.

2- Defending the body by digesting the invading organisms.

3- Digestion of the useless mitochondria and ER forming **residual bodies.**

4- In the kidney, they hydrolyse the filtered protein helping their reabsorption.

6- Peroxisomes:

- They are small organelles that contain several enzymes involved in **lipid metabolism**.

7- Coated vesicles:

- They contain **digestive** enzymes and are called secretory granules or **zymogen** granules as secretory granules of pancreatic acinar cells.

8- Endosomes

- They are lipoprotein microbodies present under the cell membrane .

- They facilitate interance of molecules by a **selective** mechanism called receptor mediated- endocytosis, after formation of **Ligands**.

9- Annulate Lamellae:

-They are uncommon membranous organelles.

-They consist of stacks of parallel lamellae with numerous pores or annuli (as nuclear envelop) and are attached to rER at their ends.

-**Site**: in rapidly growing cells as germ embryonic cell and tumor cell.

-**Origin** &**function**: are unknown, however they be related to rER or nuclear envelop or may convey materials from nucleus to cytoplasm.

B- Non- membranous cell organelles:

1- Ribosomes:

-They are non- membranous Cell organelles.

-By LlM: they stain blue with hematoxylin and methylene blue.-They are formed in the nucleolus.

-They are formed of ribo-nucleoprotein (RNA+ protein).

-It may be: **Free** ribosomes, **attached** ribosomes to the rER, Form **isolated bodies** (called **Nissl's)** granules in nerve cell, form spiral structure called **polysomes**, form fragmented structure called **microsomes**.

- By **E/M**, they are formed of 2 subunits (small and large sub-units) with a polypeptide chain between its units.

-Function:

-**Free** ribosomes form the cytoplasmic protein.

-A**ttached** ribosomes form the secreted protein in the form of hormones and enzymes that are released from the cells as secretory granules by exocytosis.

2- Microtubules:

-They are non- membranous Cell organelles. They are present in all kinds of cells. They are cylindrical filamentous structure (**24nm** in diameter), formed of protein known as tubulin. They appear as tiny **circle** in cross section.

-Function:

- Act as cell skeleton.

- Share in formation of cilia& flagella.

- They facilitate transport of substance through the cytoplasm.

- They play an important role during cell division.

3-Centrioles:

-They are non- membranous Cell organelles, present in all kinds of cells **except** mature nerve cell and erythrocytes.

-They are 2 tubular structure present **perpendicular** to each other at supra-nuclear position. They can be seen by LlM with **iron Hx** stain.

-By ElM: the wall ofcentriole is formed of **27** microtubules that arranged in **9** groups, each is formed of **3** microtubules **(9 peripheral triplets).**

Function of centrioles:

1- During cell division, they form microtubule organizing center (MOC), from which mitotic spindles arise.

2-They form cilia and flagella.

4- Cilia &Flagella:

A- **Cilia:** they non membranous Cell organelles, hair like processes extending from the free surface of certain cells.

-By ElM: each cilium is formed of:

1-Basal body= **27** microtubules as **centriole**.

2-The Shaft= **18** peripheral microtubules arranged as **9** peripheral **doublets**.

In the center, there is **2** more microtubules (2 central singlets).

3- Rootlet= **7** microtubules embedded into the cytoplasm of the cell.

Function:

-They push fluids or small bodies in one direction.

-They act as photoreceptors in **rods** and **cones** of the retina.

B-**Flagella**:

- They are similar to cilia in structure but are longer.

-**Site**: tail of mature sperm.

5- Cytoplasmic Filaments:

Types:

1-**Thin filamenets** or **Actin** filaments: which are present in muscles.

2- **Thick filaments** or **Myosin** filaments: which are present also in muscles.

3- **Intermediate** filaments as:

a- **Keratin** in epithelial tissue.

b- **Vementin** in fibroblasts.

c- **Dysmin** in muscles.

d- **Neuro-filaments** in nerve cells.

e- **Glial-filaments** in neuroglia cells.

C- Cell Inclusion:

-These are accumulated substance in the cell. It may be:

1- **Carbohydrates** as glycogen, present in muscle and liver cell, stained by Best carmine or PAS stains. By ElM, it appears as α & β granules.

2- **Lipids**: present as fat droplets and stained by Sudan III, sudan black and osmic acid.

3- **Pigments**: they are of 2 types:

A- **Endogenous pigments** which are synthesized by the cell as **haemoglobin** (formed by RBCS), **melanin** (formed by melanocytes) and **lipofuscin** which are the accumulated non-digested old lysosomes (present in nerve cell and cardiac cell in old age).

B- **Exogenous pigments**: which comes from outside to be accumulated in the cell as: carotene, carbon and dust particles, lead and silver particles and tattoo marks.

The Nucleus

-It is rounded or elongated structure present in all eukeryotic cells except mature erythrocyte.

-The **number**: each cell has one nucleus, some cells are binucleated (as liver cell). Other has many nuclei (as osteoclast and skeletal muscle cell).

-**Shape**: It may be rounded, oval, rod- shaped, bilobed or kidney shaped.

-**Site**: It may be central, basal or eccentric in position.

-**Stain**: it is basophilic due to presence of DNA& RNA.

-**Size**: it varies between 5-10 nm, but it may be so **small** as granular cell of cerebellum, or so **large** as megakaryocyte of bone marrow.

Structure of nucleus: It is formed of 4 main components:

1- nuclear membrane. **2- nuclear sap**

3-nucleolus **4-chromatin**

1-Nuclear Membrane:

-It is basophilic membrane that surrounds the nucleus and disappears during cell division.

-By L/M: it appears as single basophilic line.

-By E/M: it is formed of 2 thin membranes separated by peri-nuclear space:

A-The **inner nuclear membrane** has chromatin granules on its inner aspect.

B-The **outer nuclear membrane** has many ribosomes on its outer surface.

-The outer and inner nuclear membranes have the same tri-laminer appearance of the cell membrane.

-The nuclear membrane has many **nuclear pores** which are covered by **diaphragm**.

-The nuclear pores have a complex structure called **nuclear pore complex**.

-Nuclear pore complex (NPC):

-It is a complex structure that spans the 2 nuclear membranes at regular intervals. It is about 80-100 nm in diameter. It is formed of **4 proteins**:

A-The Scafold: Is formed of **8** protein subunits called **nucleoproteins** arranged in **octagonal** barrel shaped structure (so called ***scafold***).

This **scafold** is inserted between **2 rings**; **Outer** cytoplasmic and **Inner** nucleoplasmic rings which maintain fusion of the 2 nuclear membranes together. The scafpld provides **simple** diffusion channels.

B-The Transporter: It is the central protein plug (**central hub**) that is supported by the scafold. It is supported by **8** radially arranged **spokes**

that converge inwards from the subunits to it. It is responsible for bi-directional transport of proteins via **receptor- mediated transport**.

C-Thick Filaments:

-They are **8** short protein **fibrilis**, measure about **3** nm in diameter, radiate out into the cytoplasm from the cytoplasmic ring of the scafold.

-They act as a **way** for the binding of **proteins** that are to be transported to the nucleus.

D- The Basket:

-It is **8** filaments (100 nm in length) extending from the **nucleoplasmic ring** of scafold to a **smaller ring** located in the nucleus. It looks like a basket (hence it is named). It is believed to be related to **transport** of RNA.

-Function of NPC:

1- It allows **passive** movement across the nuclear envelop (9-11 nm particles) through channels of scafold.

2- It allows **active** transport of substance (more than 11nm wide).This needs **energy** (from ATP) to **widen** the distance between the radial spokes and the central hub.

3- It allows **selective** transport via **receptor mediated** transport via the transporter (central hub).

4- **Transport** of RNA from the nucleus to the cytoplasm via the **basket**

2- The Nuclear Sap:

- It is a colloidal clear solution which is formed of nucleo-proteins, enzymes, DNA, RNA, lipids, Ph+, Ca+, K+. It is known as inter-chromatin substance.

- The nucleus may be open face (**Vesicular**) when it has large amount of nuclear sap, or **condensed** when it has little amount of nuclear sap.

Function: it provides a medium in which ribonucleic acids (ribosomal, transfer& messenger RNAs) move towards the nuclear pores.

3- Nucleolus:

-It is rounded structure, basophilic in staining, rich in RNA and is surrounded by chromatin materials.

-It **disappears** during cell division and **reappears** in the new daughter cells.

-It enlarges in **size** in rapidly growing cell and in cells that are actively synthesizing protein.

Structure:

-By L/M: It appears as basophilic **sponge** like structure.

-By E/M, it consists of three structures:

1- Nuclear Organizer DNA (**Pars amorpha**): it is DNA molecule that contains sequence of bases coding for rRNA.

2-**Pars fibrosa**: it is made up of densely packed ribo-nucleoprotein fibers after being transcribed from DNA(newly formed RNA).

- **Both** pars amorpha and pars fibrosa look like **Christmas tree.**

3-**Pars granulosa**: which contain mature ribosomes.

4- Chromatin:

-By L/M: they are the basophilic particles which form the chromosomes during cell division

-It is formed of DNA and histone proteins.

-It is presents in the form of:

1-**Euchromatin** (extended):it is active in protein synthesis.

2-**Heterochromatin** (condensed) or inactive which appears by E/M as:

1- **Peripheral** chromatin which lies close to the inner side of nuclear membrane.

2-Chromatin **Islands** which scattered between nuclear membrane and nucleolus.

3-**Nucleolus- associated** chromatin which represent the condensed chromatin materials around the nucleolus.

Function of chromatin:

1-It directs and guides the process of protein synthesis.

2-It stores the genetic information of the individual.

Nucleic Acids:

-They are the bases of life as they control the cellular functions.

-They are of 2 types:

1- DNA (Deoxy-Ribonucleic acid):

- It represents the essential hereditary substance which constitutes the genes.

- Each DNA molecule is formed of 2 molecular chains bound together in the form of a double helix.

-Each helix (chain) is formed of alternating phosphate and sugar (deoxyribose) groups.

-The 2 chains of DNA are linked transversely together laterally from each **sugar** group.

-There are **4** nitrogenous bases in the DNA molecule which are: Adenine, Thymine, Guanine and Cytosine.

2-RNA (Ribonucleic Acid):

-it is similar to DNA with the following **difference**:

1-DNA is found in the nucleus mainly (and in mitochondria), while RNA is present in the nucleus and cytoplasm.

2-DNA is formed of double strand helix, while RNA is formed of single strand.

3-DNA has deoxy-ribose sugar, while RNA has Ribose sugar.

4-DNA has nitrogenous base Thymine (T), while RNA has Uracil (U).

5-DNA is one type, while RNA is of 3 types; rRNA, tRNA and mRNA.

III-Cytogenetic:

-It is the science which studies the heredity at cellular level through cytological techniques and chromosomal preparations.

The cell Cycle:

-It is a series of changes that take place in a cell during its division and in rest (interphase).

-In **cell division**, the cell divides its nucleus and cytoplasm giving 2 daughter cells.

- In **interphase**, the cell increases its size and replicates its genetic materials.

1- Interphase:

-It is the period between 2 successive divisions.

-It is divided into **3 main stages**:

1- G1 stage:

- It takes about **8** hours, starting from the end of mitosis to the next stage (S stage).

-During this stage, **macro-molecules** needed for synthesis of DNA are formed, the **nucleoli** are re- established and the **centrioles** begin to duplicate.

2- S stage:

-It is the synthetic period of the cell cycle.

-It takes about **7** hours.during which, the genome is duplicated i.e. the amount of **DNA** is **duplicated**. The cell now contains double the normal complement of its DNA and all the nucleo-proteins are incorporated into DNA molecules forming the chromosomes (46-d chromosomes).

-Duplication of centriole is completed in this phase.

3- G2 Stage:

- It takes about **4** hours, starting from **S**- stage to the **beginning** of mitosis.
- **RNA** and **proteins** needed for cell division are synthesized.
- The **energy** required for mitosis is stored.
- The **tubulin** of microtubules required for mitotic spindle formation is assembled.

II- Cell Division:

-Types:

1- **Mitotic cell division**: it occurs in all cells of the body except germ cells of testis and ovary.

2-**Meiotic cell division**: it occurs in germ cells of testis and ovary.

3-**Amitotic cell division**: it occurs in lower animals as amoeba, certain cells of the embryo, Placenta and mitochondria of the eukaryotic cell.

Mitosis:

- It is a short phase of cell cycle. It lasts form few minutes to one hour.

-It includes 2 phases; division of nucleus by a process called **karyokinesis** and division of cytoplasm by **cytokinesis**.

Karyokinesis:

-The karyokinesis includes the following 4 stages:

1- Prophase stage: in this phase, the following occur:

-Migration of centrioles towards the poles of the dividing cell.

-Disappearance of nucleolus and nuclear membrane by phosphorylation of nuclear lamins.

-The formed chromosomes become shorter and thicker.

2-Metaphase stage:

-The chrosmosomes are arranged in the equatorial plane of the dividing cell.

-Each chromosome is formed of 2 chromatids connected by the centromere.

-**Kinetochores** are rounded bodies present at the centromeres, they form the chromosomal microtubules.

-Complete formation of **mitotic spindles** occurs to form **Spindle Apperatus** which is formed of:

a- Cytoplasmic (**Polar**) microtubules: formed by centrioles at MTOC.

b-**Chromosomal** microtubules: formed by the kinetochores of the chromosomes.

c- **Astral** microtubules: arise from MTOC radiating out toward the periphery of the cell. They are short and look like sun rays.

3- Anaphase stage:

-During this phase the chromosomes split longitudinally into 2 sister chromotids.

-The sister chromatids start to pull apart towards the opposite pole by the aid of kinetochore microtubules.

4- Telophase stage:

-Each set of chromosomes has reached its respective pole.

-The nuclear envelop reconstituted by de-phosphorylation of nuclear lamins

-The chromosomes uncoil and become organized into heterochromatin and euchromatin of interphase cell.

-The nucleolus is organized from NOR.

-Cleavage furrow starts to appear at the middle of the cytoplasm denoting beginning of **cytokinesis**.

II-Cytokinesis:

-It is the process of division of the cytoplasm.

-It starts by formation of cleavage furrow at the middle of cytoplasm which continues to deepen until the **midbody** is formed (which is formed of small bridge of cytoplasm and polar microtubules) which connects the2 daughter cells together.

-The midbody is surrounded by a **contractile ring** formed of actin and myosin filaments.

-Contraction of contractile ring leads to separation of the 2 daughter cells.

-Finally the 2 daughter cell were formed, each one is identical in every respect to the mother cell and has diploid number of S chromosome.

II- Meiosis:

-It occurs in germ cells of testis and ovary.

-Each mother cell gives 4 daughter cells, each has haploid number of S chromosomes.

-It consists of 2 successive nuclear and cytoplasmic divisions.

-The 1st meiosis:

- It involves separation of the 2 homologus chromosomes giving rise to 2 nuclei, each contains 23 D chromosomes . It occurs through 4 stages:

Prophase I:

-It is long period, including 4 phases:

a- **Leptotene** stage: the chromosomes are long thin threads.

b- **Zygotene** stage: the homologous chromosomes are paired together**.**

c**- Pachytene** stage**:** The chromosomes become more shorter and thicker and each chromosome appears to be formed of 2 chromatids joined together, so the homologous chromosomes referred as **tetrad**.

d-**Diplotene** stage: the non- sister chromatids exchange the genetic material at crossing over site called **chiasmata** (synaptonemal complex).

e-**Diakinesis**: The homologus chromosomes are now separated from each other at chiasamata.

-The rest of this stage is similar to that of mitosis (disappearance of nuclear membrane, nucleolus and movement of each centriole to opposite pole.

2- Metaphase I:

-The homologous chromosomes are arranged at the equator of the cell by the aid of mitotic spindle.

3-Anaphase I:

-Each set of homologous chromosomes are moved by the aid of mitotic spindle to one pole, thus, each pole has half number of D chromosomes(23 D chromosome).

-The process of cytokinesis starts in this stage.

4-Telophase I:

- Now each pole has half number of chromosomes. The nuclear membrane is reformed, the nucleolus reappears and the cytokinesis is completed.

- The net result of this stage is formation of 2 daughter cells, each one has half number of chromosomes

-The **2nd meiosis**:

- The cells enter the second meiosis directly **without** passing through interphase (**no duplication of DNA**).

- It comprises the 4 stages; **prophase** II, **metaphase** II, **anaphase** II and **telophase** II which is similar to mitosis.

- In **metaphase** II: the 23 d chromosomes are arranged in the center.

- In **anaphase** II: each chromosome splits into 2 chromatids, thus each daughter cell has half number of chromatids (23S).

- In **telophase** stage: The cytokinesis is completed and the net result is formation of 4 daughter cells, each one has half number of S chromosomes (23S).

Difference between Mitosis & Meiosis:

-Mitosis gives 2 daughter cells, meiosis gives 4 daughter cells.

-Mitosis gives cells with full number of chromosomes (46 S), while meiosis gives cells with half number of chromosomes (23 S).

-**Crossing** over occurs in meiosis but not in mitosis.

Chromosomes

-They are basophilic bodies present in the interphase nucleus.

-They are formed of DNA molecule in the form of double helix associated with histone and non-histone proteins.

-Each **mitotic chromosome** is formed of 2 threads known as **chromatids** which are connected together at point known as **centromere** (formed in the S- stage of interphase).

-The human chromosomes are 46 (23 identical pairs; 22 pairs of autosomes and one pair of sex chromosome). The sex chromosomes are XX in female and XY in male.

- The **chromosomes** are present in 2 **forms**:

1- **Interphase** Chromosome (**unduplicated** S- chromosome) which is formed of single chromatid.

2-Mitotic chromosome (**duplicated** form, D- chromosome, which is formed of 2 copies of DNA formed in the S- stage of interphase giving 2 chromatids joined at centromere).

Karyotyping:

-It is the study of the **number**, the **type**, the **arrangement** and the abnormalities of chromosomes of an individual.

-**Karyogram**: It is the diagrammatic representation of chromosomes of an individual.

Special marks of chromosomes

1-Centromere:

It is a constriction visible on metaphase chromosome that join the 2 sister chromatids together. It is essential for survival of chromosome during cell division.

2- kinetochore:

It is a pair of dots, one on each chromatid. It is the **organ** of **movement** of chromosome during division as it houses **a microtubule organizing center** (MTOC) called chromosomal MTOC, from which arise chromosomal mitotic spindle of cell division.

3-Nucleus Organizer Region (Ag NOR):

It is a region called **satellite** attached by a stalk to the **acrocentric** chromosomes (no.13, 14,15, 21& 22), from which arise the **nucleolus** of interphase cell. It has multiple repeated copies of genes for rRNA synthesis. It has great affinity for **silver** stain so called Ag NOR.

4- Telomere:

It is the physical end of chromosome. It acts as a protective cap to chromosome ends. It is maintained by **telomerase enzyme**. It plays an essential role in sealing the ends of chromosomes and maintaining its stability.

Classification of Chromosomes

1-According to the length: it may be **short** (as 21,22 &Y), **medium** (as 6-12 &X) or **long** (as 1,2&3).

2-According to the position of centromere:

- **a- Metacentric**: centromere lies near the middle.
- **b- Sub-metacentric**: centromere lies midway between the center and the end.
- **c- Acrocentric**: the centromere is present near the end.
- **d- Telocentric**: the centromere is present at the tip of chromatids (not found in human).

3-According to the length and position of centromere: **Danever** classifies the chromosomes into 7 groups:

-Group A: longest metacentric chromosomes (as 1-3).

-Group B: long sub-metacentric chromosomes (as 4&5).

-Group C: medium sub-metacentric chromosomes (as 6-12 & X).

-Group D: medium acrocentric chromosomes (as 13-15).

-Group E: meta- and sub- metacentric short chromosomes (as 16-18).

-Group F: short metacentric chromosomes (as 19&20).

-Group G: short acrocentric chromosomes (as 21, 22 &Y).

4-**According to the gene complement:** Somatic or sex chromosomes, D chromosome or S chromosome.

5-According to banding patteren: a recent technique for inducing specific patterens of **light** and **dark** bands along metaphase chromosomes.

Chromosomal Abnormalities:

-Causes:

1- Infection with German measles. 2- Exposure to radiation.

3-Auto-immune diseases. 4- Pregnancy in old woman.

5- Presence of chromosomal imbalance in the parents.

Types of chromosomal abnormalities

1- Numerical abnormalities:

It means changes in the number of chromosomes due to addition or loss of one or more chromosomes.

-The ova or sperm has **haploid** number of chromosome (23, 1n).

-The somatic cell has **diploid** number (46,2n).

A- Polyploidy: it means abnormal duplication of the **haploid** number of chromosomes e.g. **triploidy** (3n), or **tetraploidy** (4n).

B-Aneuploidy: it means abnormal **addition** or **loss** of one chromosome. It may involve **autosomes** or **sex** chromosomes.

- **Aneuploidy of autosome** as triosomy 21 (**Down** syndrome)

-**Aneuploidy of sex chromosome** as **Klinfelter** (47 XXY), **super female** (47 XXX) or **Turner** syndrome (45 X).

2- Structural abnormalities:

It means change in **structure** of the chromosomes which may be:

1- **Deletion**: means loss of part of chromosome.

2- **Addition**: means addition of a genetic material to a chromosome.

3- **Translocation**: means **exchange** of genetic materials between 2 chromosomes having broken ends.

4-**Inversion**: means inversion of genetic materials on chromosome after occurrence of 2 breaks and reunion of the inverted area.

5- **Iso-chromosome**: means abnormal **transverse** division of **centromere** instead of normal longitudinal division resulting in production of one chromosome with 2 **long** arms and another chromosome with 2 **short** arms.

6- **Ring chromosome**: means break on both terminal ends of chromosome followed by union of the 2 steaky ends together forming ring chomosome.

VI-Tissues of the body

The basic tissues of the body are:

1- Epithelial tissue 2-Connective tissue

3- Muscular tissue 4-Nervous tissue

I-The epithelial tissue:

- Characters:

1-It may be ectodermal, endodermal or mesodermal in origin.

2-It is formed mainly of cells with few intercellular substances.

3-The cells rest on basement membrane.

4-It is avascular (no blood ,no lymphatic penetrate it).

5-It is highly innervated.

6-It has high power of regeneration.

Types of epithelium:

1- Simple Epithelium 2-Stratified Epithelium

3-Glandular Epithelium 4-Neuro- Epithelium

5-Myo-epithelium

Types of simple epithelium:

1- Simple squamous. 2- Simple cubical.

3- Simple columnar. 4-Simple columnar ciliated.

5-Pseudo- stratified columnar. 6- Pseudo-stratified columnar ciliated.

1- Simple squamous epithelium:

-it is formed of single layer of flat cells resting on basement membrane.

- **site**:

1- lining the wall of blood vascular system as heart, blood vessel.

2- lining the serous cavities as pleura, pericardium and peritoneum.

3- lining lung alveoli, Bowman's capsule and loop of Henl in the kidney.

-**Function**: it acts as thin, smooth surface facilitating the flow of fluids, easy movement, gas exchange, filtration and diffusion.

2- Simple cubical epithelium

-It is formed of single layer of cub-like cells with central rounded nucleus.

-**Site**:

1- Secretory units as thyroid follicle, acini of salivary glands, pancreas and sweat glands.
2- Convoluted tubule of the kidney.
3- Small ducts of the glands.
4- Covering the eye lens.

-**Function**:

- It is responsible for **secretion** as in glands or **absorption** as in the kidney.

3- Simple columnar epithelium:

-it is formed of single layer of tall columnar cells with basal oval nuclei.

Site: stomach, cervical canal of uterus and convoluted tubule of the kidney. -

Function: Secretion or absorption.

4- Simple columnar ciliated epithelium

-It is formed of single layer of columnar cells with basal oval nuclei. Their surfaces are covered by cilia.

-**Site**: uterus and fallopian tube, central canal of spinal cord and small bronchioles of lung.

Function: its cilia beats in one direction for movement of substances.

5- Pseudo-stratified columnar epithelium:

-it is formed of single layer of columnar cells resting on clear basement membrane, some of the cells do not reach the surface, therefore their nuclei are present at different levels forming different rows.

Site: vas deferens, large ducts of salivary glands , upper part of male urethra.

6- Pseudo-stratified columnar ciliated epithelium:

-It is formed of single layer of columnar cells which are crowded over each other. Their nuclei are present in false irregular rows. Their surfaces are covered with cilia.

-The goblet cells are present between the columnar cells.

Site: respiratory system.

Function: the cilia of this epithelium beat in one direction to remove dust and foreign substance away from the body.

II- Stratified epithelium:

- It is formed of many layers of cells. It is classified according to the shape of the cell in the top layer into:

1- Stratified squamous.
2- Stratified columnar.
3- Stratified columnar ciliated.
4- Transitional epithelium.

1- Stratified squamous:

-It is formed of many layers of cells resting on clear basement membrane.

-The basal cells are columnar in shape, the intermediate cells are polygonal in shape while the top cell layer are flat squamous in shape.

-The surface may be covered by **keratin** layer as in the skin and its openings or **not keratinized** as in the oral cavity, cornea and vagina.

-**Function**: protection.

2- Stratified columnar epithelium:

-It is similar to the previous one but the top layer is columnar cells.

-Site: -conjunctiva of eye, male urethra**,** large duct of the glands and recto-anal junction.

3- Stratified columnar ciliated:

-it is similar to the previous one but its top cell layer has cilia.

-site: fetal esophagus, nasal surface of soft palate and laryngeal surface of epiglottis.

4- Stratified cuboidal epithelium:

-It is similar to stratified columner, but its top layer is formed of cubical cells.

site: ducts of sweat glands.

5- Transitional epithelium:

-It is a stratified type, formed of several layers resting on irregular basement membrane.

-The top layer has convex outer surface and concave inner surface, some cells have 2 nuclei. It is covered by mucous like substance.

-The middle layers have polygonal shape and separated from each other by mucous like substance.

-The basal layer is formed of high cuboidal cells.

-**Site**: urinary system (urinary bladder, ureter and renal pelvis).

Function: It **changes** its shape according the state of the organ as when the bladder is **full** of urine, it extends to be formed of few layers of cells(2-3 layers) and when bladder is **empty**, it recoils to be formed of 5-8 layers of cells. This occurs by the aid of intercellular substance that is present in between the cells.

III glandular epithelium:

-it is classified according to:

1- Presence or absence of ducts: exocrine (salivary gland), endocrine (thyroid) or mixed glands (pancreas).

2- Number of cells: unicellular gland (goblet cell) and multicellular as salivary gland.

3-Mode of secretion:

- **Merocrine** (no change in cell as salivary gland)
- **Apocrine** (the apical part of the cell is lost as mammary gland)
- **Holocrine** (the whole cell is lost with the secretion as sebaceous gland).

4- **Type of secretion**s (serous, mucous, fatty, waxy and watery).

5- Shape of secretory part (tubular, alveolar or tubuloalveolar).

IV-Neuro- epithelium:

-In this type, the epithelial cell acts as sensory receptor for special stimuli.

-They are provided with small hairs on their free ends, while their bases are provided with sensory nerves.

Site:

-Taste buds in the tongue -Organ of corti in the inner ear.

-Olfactory epithelium in nose.

-Taste bud is formed of receptor cells, supporting cells and basal cells.

Function of neuro-epithelium: it transmits sensation from the peripheral organs to the CNS as sense of taste, smell, vision and hearing.

V- Myo-epithelium:

-The cells have **actin** microfilaments in their cytoplasm, so they have **contractile** function.

-They are present around the secretory cells (between the cells and their basement membrane).

-They have branched cytoplasm and so called **basket** cells.

-**Site**: mammary gland and salivary gland.

Function: they help secretory cells to squeeze and evacuate the secretion out of the gland.

Function of epithelium:

1-**Protection** (surface epithelium) 2-**Secretion** (glandular epithelium)

3- **Absorption** (intestinal epithelium) 4-**Sensation** (neuro-epithelium)

5-**Reproduction** (cells of testis and ovary).

6-Excretion (cells of kidney and sweat gland).

II-Connective tissue

Characters:
-It is mesodermal in origin, it acts as packing material that supports, binds and connects the various tissues and organs together.
-It is formed of connective tissue **cells**, **fibers** and soft jelly- like **matrix**.
-It is richly supplied with blood vessels and nerves.

1-Connective tissue cells

A- **Fixed cells**: they are long lived cells as fibroblasts, histocytes (fixed macrophages), fat cells (adipocytes), mesenchymal cells, pericytes, endothelial cells and reticular cells.

B- **Free cells**: they enter the connective tissue from the blood, they are short- lived motile cells as free macrophages, plasma cell, mast cell and leucocytes.

I-The fixed cells of connective tissue:

1-Fibroblast cell:
-it is irregular, or fusiform in shape.
-it has basophilic cytoplasm rich in rER, Golgi complex, mitochondria and secretory granules.
-it has pale nucleus with dark nucleolus.
-The old non- active fibroblasts are called **fibrocytes** which have an acidophilic cytoplasm and dark nuclei.
-**its function** is 1- formation of connective tissue fibers and connective tissue matrix and 2- it helps in closure and healing of wounds.

2-Histocytes (fixed macrophages):
-They have irregular cell membrane and darkly stained nuclei.
-The cytoplasm is rich in lysosomes, multiple phagosomes and residual bodies.
-It can be stained with **vital stain** as trypan blue or indian ink.
- **Functio:** 1- Phagocytosis of foreign bodies. 2- Trapping and transport of antigen. 3- it can fuse with each other to form **giant cell** which has phagocytic function.

3-Fat cell (adipocytes):

-it is of two types:

1- **unilocular** fat cell which is rounded or oval in shape, has single large globule of fat filling the whole cell cavity and peripheral flattened nucleus (give the cell **signet- ring** appearance).

2- **multilocular** fat cell: it is rounded or oval in shape, has central rounded nucleus and multiple globules of fat filling the whole cytoplasm.

- **Function**:

1- Storage of fat.

2-Support and protect internal organs as kidney.

3- Acts as heat insulator.

4- Meschenymal cell:

-it is an embryonic, undifferentiated cell.

-it has pale cytoplasm with central oval nucleus and irregular cell membrane with multiple cell processes. It is usually surrounded with jelly –like matrix.

-**Function**: it can differentiate to give other types of connective tissue cells.

5- Pericytes:

-They are present in the wall of blood capillaries between the basement membrane and their endothelial lining.

- They have irregular cell membrane with multiple cell processes and oval nuclei.

- **Function**: they can be changed to **fibroblasts** and **smooth muscle** cell during repair of connective tissue and blood vessels.

6- Endothelial cells:

-They are mesodermal in origin. They are flat cell with flat nuclei. They line the wall of blood vessels. By **E/M**, they show endocytotic pits and vesicles.

-**Function**:-

-They can form type **4 collagen** and **collagen** of the capillary basement membrane.

- They can divide to form new blood capillaries.

7- Reticular cells:

-They are modified fibroblast cells which have irregular cell membrane with multiple processes and central rounded nuclei.

Functions:

-They form the reticular **stroma** of the organs as spleen, lymph node and thymus.
-When stimulated by **antigens** they change into **phagocytic** cells.
-They remove the cell debris from lymphatic tissues

II-The free cells of connective tissue:

8- Plasma cells:

-**Origin**: from B- lymphocyte of blood after migration to the connective tissue.
-**Shape**:
- By L/M: It is **rounded** cell with eccentric rounded nucleus and prominent nucleolus. The nucleus takes the shape of **cartwheel** or **clock-face** appearance. The cell exhibits deeply basophilic cytoplasm with supra-nuclear –ve Golgi image (not stained with HX, E).
-By E/M, the cell is rich in rER, Golgi complex and mitochondria.
-**Function**:
-They produce antibodies.
-They defend the body against infection.

9- Mast cell:

- **Origin**: it arises from **hematopoietic** stem cell of bone marrow.
- **Shape**: It is oval cell with granular cytoplasm and eccentric rounded nucleus. The cytoplasm is rich in **heparin** granules which stain **purple** with methylene blue stain. This **change** of color of the stain (from blue to purple) is called **metachromasia**.

Functions:
- Secretion of **heparin** (anticoagulant).
- Secretion of **histamine** (antiallergic).

10- Pigment cell (melanophore):

-They are connective tissue **macrophages** that engulf melanin pigment.
-They are large cells with multiple processes and large nucleus. Their cytoplasm is rich in melanin granules called **melanosomes.**
-They are seen in the dermis of the skin and can be stained with vital stains.
Functions: They carry melanin pigment.

11-Leucocytes:

-They are blood leucocytes which migrate from blood to the connective tissue.

- They are neutrophils, eosinophils, basophils, monocytes and lymphocytes.
-They increase in cases of infection to phagocytose the microorganisms.

12- Free macrophages:

-**Origin**: they arise from blood **monocytes**, which migrate to connective tissue and then change into free macrophages.
-**Shape**: They are branched cells with irregular cell membrane and oval eccentric nuclei. The cytoplasm is rich in lysosomes, multiple residual bodies.
-**Function**:
-They are phagocytic cells and share in immune defense of the body. They secret **collagenase** and **elastase** enzymes and **lysozymes**.

II- Connective tissue fibers

I-White collagen fibers:

-They appear **white** in fresh state. They are in the form of **bundles**. Each bundle is formed of group of **fibers**. The bundle branches but the individual fiber does not branch. Each fiber is formed of group of **fibrils**, each fibril is formed of **tropocollagen** molecules.
Types:
-**Collagen type I**: It is found in tendon of muscle and it is formed by fibroblast cells and osteoblasts.
-**Collagen type II**: It is found in cartilage and it is formed by chondroblasts.
-**Collagen type III**: It is found in blood vessels and it is formed by smooth muscle cells.
-**Collagen type IV**: It is present in the basement membranes and formed by epithelial cells.
-Collagen type V: It is found in the fetal membranes, blood vessels and around the muscles. It is formed by fibroblasts.
Stain: it stains blue by **Mallory stain**.

II-Yellow elastic fibers:

-They are thin, branching, slender and long fibers. They appear yellow in great amount.
-They are digested by elastase enzyme and resist boiling and hydrolysis by acids or alkalies.
-They are formed of mass of protein called **elastin** surrounded by micro fibrils, formed of **fibrillin** protein.
-They are formed by **fibroblast** cell and **smooth muscle** cell.
-They are stained brown with **orcein** stain.

III- Reticular fibers:

-They are very fine, delicate fibers that form the stroma of the glands as liver and salivary glands.
-By L/M, they stain **black** with silver stain, **red** with PAS and **green** with Sirius red. They can also be seen by **polarizing** microscope.
-They are formed of collagen type III, proteoglycan and glycoproteins.
-They are formed by fibroblasts and smooth muscle.
-Function: they form the reticular meshwork of the stroma of the organs.

III- Connective Tissue Matrix

-It is a jelly like substance formed of acid muco-polysaccharide.
-It is formed by fibroblast cells. It is present among connective tissue cells and fibers.
-It allows diffusion of tissue fluids, nutrients and waste products between the tissues of the body.

- **Types of connective tissue:**

1- Loose areolar connective tissue.
2- Adipose connective tissue.
2- Mucous connective tissue.
4-white collagenous connective
5- Yellow elastic connective tissue.
6-Reticular connective tissue.

1-Loose areolar c.t.:

-It is present in all tissues of the body. It binds the tissues together and surrounds the organs.
-it is formed of all types of c. t. fibers, cells and embedded in a loose matrix.
Sites:
- Around organs and blood vessels and in subcutaneous connective tissue.
- Submucosa and serous membranes as pleura, peritoneum and pericardium.

2- Adipose connective tissue:

-It is similar in structure to loose areolar c. t., but it is rich in fat cells.
Types: It may:
1-**Unilocular adipose c. t.** (**white**):

- it is formed of **fat cells** that have one large globule of fat filling the whole cytoplasm and push the nucleus to the periphery giving the cells **signet ring appearance**.
-Its **site** is under the skin, mammary glands, around the kidney and in between the viscera.
-Its **function**: it acts as heat insulator, as fat storage area in the body and support the kidney and other organs.

2-**Multilocular adipose c. t. (**Brown):
- it is formed of **fat cells** that have **central** rounded nucleus and multiple small globules of fat droplets filling the whole cytoplasm.
- It is called **brown** because it is rich in blood capillaries and pigments.
- Its **site** is in the foetus, new born infants and in the scapular, axillary and mediastinal regions.
-Its **function** is to provide the heat for new born baby.

3-Mucous (mucoid) connective tissue:
-It is formed of c. t. **cells** mainly mesenchymal cells, very fine collagen **fibers** and mucoid **matrix** which is soft jelly- like substance rich in mucin.
-**Site**:
- in embryonic tissue as **umblical cord** between its 2 arteries and its vein.
- in vitrous humour of the eye ball and pulp of growing teeth.
- Its **function** is: support the organs.

4-White collagenous connective tissue:
-It is formed mainly of **white collagen** fibers and **fibroblast** cells with little amount of **matrix**.
-Types: it may be of:
1-Regular type: which is formed of **regularly** arranged collagen fibers (in the form of **bundles**) separated by fibroblasts (called **tendon cells**).
-Its **sites**:
- The tendon of muscles and ligaments.
- The cornea of the eye.
2-Irregular type: it is formed of **irregularly** arranged collagen bundles separated by fibroblasts and little matrix.
-Its **site**s:
- Deep fascia and dermis of the skin.
- Perichondrium of cartilage.
- Sclera of the eye.

5-Yellow elastic connective tissue:

-It is **elastic** and stretchable type of connective tissue.
-It is **yellow** in fresh state. It can be stained with **orcein stain**.
-It is formed of condensed regular **elastic fibers** separated by **fibroblasts**.
-Its **sites** are:
- Aorta and big arteries (to maintain continuous blood flow).
- Lung bronchi, bronchioles and alveoli (to facilitate its expantion).
- Ligamentum nuchae (in the back of the neck) and ligamentum flavum (between vertebrae) to facilitate easy movement of the neck and trunk.

6-Reticular connective tissue:
-It is formed of thin immature collagenous fibers that called **reticular fibers** and **reticular cells** which are modified fibroblast cells having multiple cell processes that connected with each other by intercellular junctions.
-**Sites and function**: It forms the reticular framework (stroma) of the organs as spleen, lymph node, liver and bone marrow.

Cartilage

-Characters:
-It is a **firm** type of connective tissue, **flexible** and **strong**.
-It consists of cartilage **cells** (chondrogenic cells, chondroblasts and chondrocytes), **fibers** (white fibers and yellow elastic) and **matrix** (formed of chondro-mucoproteins and chondroitin sulphate).

-Function of cartilage:
1- It supports the bone in carrying the body weight.
2-It facilitates movement of joints.
3-It keeps the air way passages patent all the time.
4-Is is responsible for growth of bone both in width and length.

-Structure of cartilage:
1-cartilage cells:
a- Chondrogenic cells:
- They are undifferentiated meschenymal cells having irregular cell membrane, lightly basophilic cytoplasm with flat nucleus and few organelles. They can differentiate to give rise to chondroblasts.

b- Chondroblasts:

- They are oval cells with basophilic cytoplasm and pale oval nucleus, present **singly under the perichondrium**. By E/M, they have rER, ribosomes and well developed Golgi complex. They form **proteins and collagen type II of the matrix.**

c- Chondrocytes:

- They are irregular in shape with basophilic cytoplasm and dark nuclei. Their cytoplasm is rich in **glycogen** and **phosphatase enzyme**. The **young** cells can divide, so they are present in groups surrounded by a **space** called **lacunae** and the group of cells called **cell nests.** They form **proteins** and **type II** collagen of the matrix.

Types of cartilage

1-Hyaline cartilage:

- It is formed of **cells**, fibers (mainly **collagen** fibers) and **matrix**.
- It is covered by **perichondrium** except the articular surface of joints.
-The **perichondrium** is formed of **outer** fibrous layer (collagen fibers, fibroblasts and blood vessels) and **inner** chondrogenic layer (formed of chondroblasts).
- **Sites**: - Costal cartilage.
  - Cartilage of nose, larynx, trachea and bronchi.
  - Long bone of foetus.
  - Articular surface of joints.

2-Elastic cartilage:

- It is similar to hyaline cartilage but the matrix is rich in elastic fibers which surround the cartilage cells.
- It has perichondrium, and it is more flexible.
- **Sites**:-Ear pinna, external auditory meatus, eustachian tube and epiglottis.

3-White fibro-cartilage:

- It does not surrounded by **perichondrium**.
-The chondrocytes are arranged into **rows** or columns and are separated by bundles of **collagen** with acidophilic matrix and blood vessels.
-**Sites**: - Inter-vertebral disc. - Semilunar cartilage of knee joint.
- Symphysis pubis. - Acetabulum and glenoid cavity.

Bone

-It is calcified ostoid tissue, formed of bone cells embedded in calcified matrix, covered by periostium and lined by endostium.
-The **bone matrix** is formed of packed layers of calcified collagenous lamellae embedded in osteoid tissue. The bone matrix is formed by **osteoblasts** and maintained by **osteocytes**.

- The bone cells:

1-**Osteogenic cells**:
-It is **mesenchymal** stem cell, found in periosteum and endosteum of bone. -It is elongated cell with oval nucleus and pale cytoplasm.
-They can differentiate into **osteoblasts** in vascular tissue and into **chondroblasts** into avascular tissue.

2-**Osteoblasts**:
-**Origin**: they arise from osteogenic cells.
-**Structure**:
- By L/M: they are oval cells with eccentric rounded nuclei. They have deep basophilic cytoplasm.
- By E/M: they show rER, Golgi complex and mitochondria. They contain phosphatase enzyme to deposit calcium in the matrix.
-**Site**: they are present mainly in the periostium and endostium of the bone.
-**Function**: formation of the matrix. They change into **osteocytes** when they are imprisoned inside lacunae.

3-**Osteocytes**:
-**Origin**: they arise from osteoblasts.
-**Structure**: they are small cells with basophilic cytoplasm and rounded nucleus. They occupy small cavity called **lacunae**. Canaliculi arise from these lacunae to communicate osteocytes together via **cell processes**. They cannot divide so they are present **singly** in their lacunae (**no cell nests**).
-**Function**: Formation of collagen and proteoglycan substances, so they maintain the bone matrix.

4-**Osteoclasts**: They are bone **phagocytic** cell.
-**Origin**: they arise from fusion of many blood **monocytes**, osteoprogenitor cells or macrophages.

-Structure: they are large cell with acidophilic foamy cytoplasm and ruffled cell membrane border. They have many nuclei up to 20 nuclei.

-Site: They are present at **bony surfaces** at depression called **Howship's** lacunae.

-Function: remodeling of bone during bone formation.

Types of bone tissue:

1- Compact bone (ivory).
2- Cancellous (spongy) bone.

I-Compact Bone:

-Site: Shaft of long bone and the outer covering of the flat bone.

-Structure: It is formed of:

1- **Periostium**: outer covering, it is formed of outer fibrous layer and inner osteogenic layer.
2- **Endostium**: it lines the inner surface of the bone. It is formed of osteogenic cells and osteoblasts.
3- **Haverstian system** (**osteon**): It is the structural unit of compact bone. It is formed of **Haversian canal** (contains blood vessel and nerves), **bone lamellae** (formed of 5-20 cocentric layers of calcified osteoid matrix) and **osteocytes** (embedded singly in their lacunae between bone lamellae).
4- **External circumferential lamellae:** they are bone lamellae with their osteocytes which run under the periostium.
5- **Internal circumferential lamellae:** they are bone lamellae with their osteocytes which run close to the endostium.
6- **Interstitial Lamellae:** They are irregular bone lamellae which run in between the Haversian lamellae.
7- **Volkman's Canals:** these are transverse canals which connect some haversian canals together, through which blood vessels can anastomose together.
8- **Sharpy's Fibers**: These are calcified ends of muscle tendons which extend from the tendon to the periostium, then deep to the bone lamellae.

-Function:

1- Calcium reservoir.

2- Weight bearing.
3- Protect vital organs as brain.

II- Cancellous Bone (Spongey Bone):

-Site: - Ends of long bone. – Ribs and vertebrae.
- Center of flat bone as skull, scapula and sternum.

-Charaters:

- It is formed of irregularly arranged plates of **bone trabeculae**.
- The **bone trabeculae** are formed of irregular bone **lamellae** with scattered **osteocytes** which are embedded between the bone lamellae.
- Multiple **bone marrow** cavities are present between the bone lamellae.
- There is **no Haversian** system in spongy bone.
- **Function**: It acts as a reservoir for the **active red bone marrow**.
-

Muscular Tissue

-Characters:

- It is one of the basic tissues of the body.
- It is of **mesodermal** origin.
- The individual cell is elongated called **myofiber**.
- The cell membrane of myofiber is called **sarcolemma**, the cytoplasm is called **sarcoplasm**.
- The sarcoplasm contains all cell organoids (mainly **actin** and **myosin** micro-filaments) and inclusion (mainly fat and glycogen).
- The muscle fiber is surrounded by connective tissue sheath called **endomesium**. The groups of muscle fibers are called muscle **bundles** which are surrounded by **perimesium.** The whole muscle is surrounded by **epimesium**.

-**Types**: the muscular tissue is classified according to the structure and function into:

1- Skeletal muscle.
2- Cardiac muscle.
3- Smooth muscle.

I-Skeletal muscle:

- It is called so because it is attached to the skeleton of the body.

- **Sites**: attached to skeleton, diaphragm, tongue, eye and upper third of oesophagus.
- By L/M, they appear long and cylindrical in shape with multiple peripheral flattened nuclei.
- The myofibrils show alternation of **dark** (A- band) and **light** (I- band).
- The **dark** band shows light area in the center called **H- zone**, while the **light** band is traversed by dark area in the center called **Z- line**. The distance between two Z- line is called **Sarcomere**.
- The **sarcomere** is the structural and functional unite of the muscle fiber. It is formed of **actin** and **myosin** filaments. During **muscular contraction**, the actin filaments **slide over** myosin filaments resulting in shortening of the **sarcomere**.
- **T- tubular system (T- triad):**
  -It is a system of **three tubules**, one is transverse tubule arises from downward invagination of sarcolemma into sarcoplasm, it is called **T-tubule** and the other 2 tubules are **terminal cisternae** of sarcoplasmic reticulum (smooth endoplasmic reticulum). The 3 tubules together are called T-Triad or **T- tubular system**. It lies at the **A-I junction** in skeletal muscle. **Its function** is to regulate the concentration of **calcium** ions within the myofibrils of the skeletal muscle (by the aid of 2 terminal cisternae) and to conduct the **wave of depolarization** to the myofibrils (by the aid of T- tubule).
- **Nerve supply**: the skeletal muscle is supplied by:
  1- Motor nerve supply called Motor- end plate at the myo-nueral junction.
  2- **Sensory supply** called muscle spindle.
  -Muscle fibers can **regenerate**, if injured, by activation of new myoblasts cells called **satellites**.

II- Cardiac Muscle:

- **Characters**:
- It is called so because it forms the wall of the heart (myocardium).
- The muscle fiber is short, cylindrical, branched and joins each other at **intercalated disc**.
- The muscle fiber has **single** rounded central nucleus.
- The sarcoplasm has all cell organoids and inclusions. It also shows cross striations of dark and light bands as skeletal muscles.
- **The T- tubular system** is formed of only 2 tubules (one is transverse-T tubule and the other is terminal cisternae). It lies at the Z- lines.

- Gap junctions are present between cardiac muscle fibers (at intercalated discs), through which ions and electrical impluses can pass.
- **Purkinje** fibers are modified cardiac muscle fibers responsible for conduction of nerve impluses.
- The muscle fibers, when died, **never regenerate** but they are replaced by fibrous connective tissue.

III- Smooth muscle:

- It is called so because it is smooth and has **no striation** (unlike skeletal or cardiac).
- It is **spindle** in shape with central oval nucleus and acidophilic sarcoplasm.
- The sarcoplasm contains all cell organoids, inclusion and **long actin** with few **short myosin** microfilaments.
- The cells are joined together with gap junctions through which electrical impulses can pass.
- The cells can regenerate from **pericyte** cells (around blood vessels).
- They **contract** by translocation of actin and myosin filaments after cleavage of **ATP**.
- **Sites**: The wall of gastro-intestinal tract, respiratory system, urinary system, media of the blood vessel wall and capsule of spleen, lymph node and digestive glands.

Nervous Tissue

-Characters:

- It is one of the basic tissues of the body**.**

- **Origin:** it arises from mid dorsal **ectoderm** of the **e**mbryo.

- it divides **anatomically** into central nervous system (formed of brain and spinal cord) and peripheral nervous system (formed of nerve fibers, and ganglia). It divides **histologically** into nerve cells and nerve fibers.

-the **nerve cell** (Neuron) is the structural and functional unit of the nervous tissue.

- Neuron:

-Size: it varies in size from **small** cell as in cerebellum to **large** cell as in cerebrum.

-**Shape**: according the number of its process, it is classified into:

1- **Unipolar neuron**: rounded cell with one process as cells of spinal ganglia.
2- **Bipolar neuron:** fusiform cell with 2 processes, one acts as **axon** and the other acts as **dendrite** as bipolar cell of olfactory epithelium, retina and inner ear.
3- **Multipolar neuron: It may be:**
   a- **Stellate neuron:** It has multiple short dendrites and single long axon as cells of sympathetic ganglia and anterior horn cells.
   b- **Pyramidal neuron**: It has pyramidal shape with multiple dendrites arise from its angles and single axon arises from the base as cells of cerebral cortex.
   c- **Pyriform neuron**: It has flask shape with multiple dendrites arise from its apex and one axon arises from its base as Purkinje cells of cerebellum.

-**Structure**: the nerve cell is formed of:
1- Cell body (perikaryon).
2- Axon.
3- Dendrites.

1-The cell body:
- It is formed of cytoplasm filled with mostly all cell **organoids** as rER, ribosomes (called **Nissl's granules**), Golgi body (around the nucleus), mitochondria (in the cell body and axon terminals) and lysosomes, neurotubules and neurofibrilis.
- It also contains cell inclusions as lipids, glycogen, lipofuscin pigments (increase with old age) and melanin pigments.
- The mature nerve cell **has no centrosome**, so it never divides.

-The dendrites:
- They are extension of the cell body
- They conduct the nerve impulses **towards** the cell body.
- They contain most of cell organoids and cell inclusions.
- They are wide at their origin and tapering at their ends.
- Their terminals have **dendritic spines** for synaptic connection.

-The Axon:
- It is a single long extension of the cell body.
- It arises at conical area of cell body called **axon hillock**.
- Its diameter is uniform through its length and it gives collateral branches.

- Its end gives multiple arborization called **axon terminals** which is rich in mitochondria and synaptic vesicles.
- Its cell membrane is called **axolemma** and its cytoplasm is called **axoplasm.**
- It may be covered by myelin sheath and it is called **mylinated fiber** or not covered by myelin sheath and it is called **non-mylinated** fiber.
- It transmits the nerve impulse **away from** the cell body.

-The neuron can be classified according to the function into:

1- **Sensory neuron:** it carries the sensation from the periphery to the central nervous system as cells of **dorsal root ganglia**.

2- **Motor neurons:** They carry the motor response from the central nervous system to the muscles as **cells of anterior horn cells**.

3-Associative interneurons: They connect the sensory and motor neurons in the brain and spinal cord.

Blood Vascular system

-It is **formed of** pump machine (**heart**), **arterial side** which is formed of big artery (aorta), distributing arteries, arterioles and arterio-venous connection (capillaries) and **venous side** which is formed of big veins (superior and inferior vena cava), collecting veins, venules and small venules which end at the arterio- venous connection.

-The wall of the blood vascular system is formed three main layers:

- **Tunica intima**: it is the innermost layer, formed of simple squamous endothelium and sub-endothelia layer of areolar connective tissue.
- **Tunica media**: it is the middle layer, formed of circularly arranged smooth muscles and connective tissue.
- **Tunica adventia**: it is the outermost layer,
- formed of areolar connective tissue.

-Character of the aorta:

1. It is long, elastic artery with wide lumen.
2. It has very thick **elastic** wall.
3. The intima shows **elastic** fibers.
4. The media is formed of **elastic**, collagen and reticular fibers with smooth muscle fibers.

5. The adventitia is formed of **elastic** fibers, collagen fibers and contains **vasa vasorum** (to supply the outer layer of the media) and vasomotor nerves.

-Characters of the medium- sized artery:

1- It has **thick** wall but narrow lumen.
2- It has **no** valve in its lumen.
3- The intima is thick and folded with **internal elastic lamina**.
4- The media is thick with some elastic fibers and many smooth muscle fibers.
5- **External elastic lamina** may be present between the media and adventitia.
6- The adventitia shows few elastic fibers and vasomotor nerves.

-Characters of the medium sized vein:

1- It has **thin** wall but **wide** lumen.
2- **Valves** may be present in some veins.
3- The intima is **thin**, not folded and has **no** internal elastic lamina.
4- The media is **thin**.
5- **No** elastic lamina between media and adventitia.
6- The adventitia is **thick**, rich in collagen fibers with vasa vasorum and nerve fibers.

-Arteries with special characters:

1-Coronary artery:

-It supplies the wall of the heart.
-the intima has well developed **internal elastic lamina.**
-there is **external elastic lamina** between media and adventitia.

2-Basailar arteries:

- They supply the **brain** tissue.
-They have **thin** wall, **thin** intima, **thin** media and **thin** adventitia.
-They have well developed **internal elastic lamina**.

3-Umblical arteries:

-They carry **venous** blood, present in umblical cord.
- They have **no** internal elastic lamina.
- **Media** is formed of inner longitudinal and outer circular muscles.

Lymphatic system

-It is formed of lymphatic tissues (organs) and lymphatic vessels.
-The lymphatic **organs** are lymph node, spleen, thymus and tonsils.
-The lymphatic **vessels** are thin walled channels that collect lymph from tissue spaces and return it to the blood circulation. Lymph circulates in only one direction toward the **heart**.
- The lymphatic vessels are **not present** in CNS, Bone marrow, cartilage, inner ear and epidermis.

I- Thymus:

- It is lymphoepithelial organ with an endocrine function.
- **Site**: it lies behind the sternum. It decreases in size and function with the progress of age.
- It is formed of two flattened lobes, embedded in the tissue behind upper part of sternum.
- It is formed of connective tissue **stroma** and **parenchyma** of lymphatic tissue.
- The **stroma** is formed of capsule, trabeculae and reticular connective tissue.
- The **parenchyma** is formed multiple lobules, each is formed of outer **cortex** and inner **medulla**.
- The **cortex** is formed of densely packed immature lymphocytes, reticular epithelial cells and T- lymphocytes.
- The **medulla** is formed of endocrine epithelial cells (secret hormones of the thymus), T- lymphocytes, macrophages and **Hassels's corpuscles** (it is concentric acidophilic mass of epithelial reticular cells).
- **The thymic barrier**: It is formed by the wall of blood capillaries and the surrounding phagocytic cells.This barrier **protect**s the newly formed T- lymphocytes from the circulating antigens.
- **Function of thymus**:

1- Secretion of hormones (as thymin, thymosin, thymopoietin and thymosterin).
2- Production of T- lymphocytes.

II- Lymph Nodes:

- They are **kidney** shaped organs of variable sizes.
- They are present in the neck, axilla, thorax, abdomen and groin.
- Each node is formed of **stroma** of connective tissue and **parenchyma** of lymphatic tissue.
- The **stroma** is formed of capsule, trabeculae and reticular connective tissue.
- The **parenchyma** is formed of outer cortex and inner medulla.
- The **cortex** is formed of cortical follicles, cortical sinuses and thymus dependent zone.
- The **cortical follicles** are formed of **germinal** center (formed of activated B- lymphocytes, macrophages and reticular cells).
- The **cortical sinuses** are the **spaces** between the capsule and the cortical follicles, lined with flat cells and contain lymphocytes, macrophages, plasma cells and lymph.
- **Thymus dependent zone**: It lies in the **deep** part of the cortex. It is rich in T- lymphocytes and post capillary venules lined with cubical cells.
- **The medulla**: formed of **medullary cords** and **medullary** sinuses.
- **The medullary cords**: it is formed of irregular collections of T-lymphocytes.
- The **medullary sinuses**: they are spaces between medullary cords. They contain lymphocytes, plasma cells, macrophage and lymph.
- **Function of lymph node:**
  1- Filtration of lymph.
  2-It has a role in humoral and cell mediated immunity.

III- Spleen:

- It is a single haemo-lymphatic intra- abdominal organ.
- Formed of **stroma** of connective t. and **parenchyma** of lymphatic tissue.
-The **stroma** is formed of capsule (covered by peritoneum and smooth muscles), trabeculae and reticular connective tissue.
-The **parenchyma** is divided into **white** pulps and **red** pulps.

-The **white** pulps are lymph follicles with central arterioles.
- The **white** pulps are formed of **4 zones** from inside to outside:

1. **Thymus dependent zone:** it surrounds the central arteriole and it is rich in **T**- lymphocytes.
2. **Germinal center zone**: it is rich in **B**- lymphocytes.
3. **Follicular zone:** It is rich in **B**- lymphocytes.
4. **Marginal zone**: It is rich in T- lymphocytes and plasma cells. It forms the periphery of the white pulp.

-**The red pulps**: they are formed of blood **sinusoids** and splenic **cords**.
- The blood **sinusoids** are wide blood spaces lined with flat cells and phagocytic cells.
- The splenic **cords** are lymphatic tissue present between blood sinusoids and white pulps. They contain blood cells, plasma cells and macrophages.
-The **spleen** is supplied with splenic artery which branches into small arteries and aretrioles to supply the white and the red pulps.

-Function of spleen:

1. It **stores** and **filters** the blood.
2. It **forms** some blood cells and destroies the old RBCS.
3. It has a role in humoral and cell- mediated immunity.

IV- tonsils:

- They are non capsulated lymphatic tissues present at the beginning of digestive system (**Palatine** tonsil and **lingual** tonsil) and respiratory system (**pharyngeal** tonsil).
- Each **tonsil** is formed of lymph follicles with or without germinal centers and diffuse lymphatic tissue between the follicles.
- The **palatine** and **lingual** tonsils are covered with stratified squamous epithelium, while the **pharyngeal** tonsils are covered with pseudo-stratified columnar ciliated epithelium.
- **Function** of tonsils:
- Protection of the body against infection.
- Inflammation of the **pharyngeal** tonsils is called **adenoids**, while palatine tonsil inflammation is called **tonsilitis**.

V- Macrophage system:

-These are phagocytic macrophage cells present all over the body.
-They can be stained with **vital** stain as trypan blue.

-They have large cell body with irregular cell membrane and large irregular nucleus. Their cytoplasm is filled with lysosomes and multiple residual bodies.

-**Sites**:
-In the blood (**blood monocytes**).
-In the brain (**microglia**).
-In the bone (**osteoclasts**).
-In bone marrow (**histocytes**).
-In the lung (**dust** cells and **heart failure** cell).
-In the liver (**Von Kupffer** cell).
-In the skin (**Langerhans** cells).
Function:

1- They have a role in immunological response.
2- Phagocytosis foreign micro-organisms.
3- Removal dead tissues, cells and old RBCs.
4- Store iron of the worn RBCs.
5- Healing of injured tissues.

Blood

-Characters:
-It is a viscous fluid, formed of blood **plasma** and blood **cells**.
-The **blood plasma** is formed of water, organic substances, inorganic substances, gases, hormones and enzymes.
-**Blood cells** are formed of **red** blood cell, **white** blood cells and **platelets.**

-Function of blood:

1- **Transport** of oxygen, nutrients and hormones **to** the tissues.
2- **Removal** of waste products and CO2 **from** the tissues through lungs, kidneys and sweat glands.
3- **Maintenance** of acid- base balance.
4- **Control** of body temperature.
5- **Protection** of the body against infection.

1-Red blood cells:

- **Number:**
- It is 4.5- 5 millons/ mm^3 in female and 5-5.5 millons/ mm^3 in **males**.
- Its decrease is called anaemia. **Anaemia** may be:
- **Deficiency** anaemia: due to deficiency of iron, and vitamin B_{12}.

- **Haemorrhagic** anaemia: due to loss of blood from nose or piles.
- **Haemolytic** anaemia: due to excess of haemolysis of RBCs.
- **Aplastic** anaemia: due to bone marrow depression.
- **The increase of red blood cell number is called polythythemia.**

B –Shape:
- It is rounded, biconcave discs and shows **rouleaux** appearance in blood stream.

Abnormal shape of RBCs:
1- **Biconvex** (spherocytosis).
2- **Pear**- shaped (poikilocytosis).
3- **Oval** (ovalocytosis).

C- Size: normal diameter is **7.5 microns** and the thickness is **1.9 microns**.
-Abnormal size of RBCs:
- **Increase** in size occurs in **macrocytic** anemia.
- **decrease** in size occurs in **microcytic** anemia.
- RBCs with **different** diameters is called **anisocytosis**.

D-**Color of RBCs**: greenish yellow due to presence of hemoglobin (Hb).
- **Abnormal color**:

1- Decrease of Hb. Is called **hypochromic** anemia.
2- Increase of Hb. Is called **hyperchromic** anemia.

E-Characters of RBCs:
-They are not true cells (have no nuclei, no organoids).
-They have plastic cell membrane.
-They are filled with hemoglobin.

White Blood Cells (Leucocytes)

-Characters:

1-They are **true** cells (having nuclei and organoids).
2-They have an **amoeboid** movement, so they can penetrate the capillary wall to the connective tissue to perform their functions.
3-They contain **no** hemoglobin.

I-Number of leucocytes: Their number is 4000- 11000/ mm^3.
- Decrease in number of leucocytes below 4000/mm^3 is called **leucopenia.**

-Leucopenia occurs in cases of:
1- Typhoid fever and influenza.
2- After exposure to X rays and after taking certain antibiotics.
- Increase in number of leucocytes above 11000/^{3} is called **leukocytosis**.
- **Leucocytosis**: it means increase number of leucocytes. It may be :
1 - **physiological**: in case of pregnancy and new born baby.
2 -**Pathological** : in cases of acute and chronic diseases.

3-Types of leucocytes:
A- **Granular leucocytes:** they have granules in their cytoplasm. They are neutrophils, eosinophils and basophils.
1- Neutrophils:
-They are about 60-70% of the total leucocytes.
-Their diameter is about 10-12 microns.
-They have single, multilobed nucleus (2-5 lobes).
-Their cytoplasm have few organoids and **two** types of granules; **Azurophilic** granules (lysosomes) rich in hydrolytic enzymes and **Specific** granules (smaller in size and numerous) and contain collagenase and alkaline phosphatase enzymes and lactoferin which is a bacteriostatic substance.
- Functions:
1- phagocytosis of microorganisms.
2- Secretion of proteolytic enzymes.
3- Secretion of **trephone** substances which help in healing of wounds.
4- Help other leucocytes to migrate to the inflammed area.
5- Stimulate bone marrow for leukocytosis.
- **Life span**: it is about 4 days, after that, they die and change into **pus** cells.
- **Nutrophilia** = Increase number of neutrophils due to infections as tonsillitis, appendicitis and any abscess formation.
-**Neutropenia** = Decrease number of neutrophils. It occurs in typhoid fever, T.B., influenza and in severe poisoning.

2-Eosinophils:

-They are 1-4% of total leucocytes.
-They are 10-15 micron in diameter.
-They have **acidophilic** cytoplasm and **bilobed** nucleus (horse- shoe).

-By E/M, they show few organelles and many granules (lysosomes).
-The **granules** contain histaminase and sulphatase enzymes.

-Functions:
1-They are attracted to the site of allergic reaction by **eosinophil chemotactic factors.**
2-They destroy histamine and sulphated substance by the **histaminase** and **sulphatase** enzymes.
3-They can phagocytose antigen- antibody complex in allergic condition.

-Life span: 8-12 days.

-Eosinophilia = increase number of eosinophils. It occurs in allergic condition and parasitic diseases.
-Eosinopenia= Decrease number of eosinophils. It occurs after treatment with cortisone.

3-Basophils:

-They are o.5-1% of total leucocytes.
- They are 10-12 microns in diameter.
- They have large **basophilic** granules and **S-** shaped **nuclei**.
-The granules contain **heparin** and **histamine** (as mast cells).
-Functions:
1- Production of heparin and histamine.
2- Phagocytic to some extent.
-Life span:10-15 days.
-Basophilia is increase number of basophils which occurs in liver cirrhosis, small box and in allergic and parasitic diseases.

II- Non- granular leucocytes: They have no granules in their cytoplasm. They are of 2 types:

1-Lymphocytes:

- They are about 20-30% of total leucocytes.
- Their diameter varies from 6-8 micron (in **small** lymphocytes) to 10-15 microns (in **large** lymphocytes). They have large nucleus.
- Lymphocytes may **B**-lymphocytes (25%) or **T**- lymphocytes (70%).
- **Lymphocytosis**= increase number of lymphocytes which occurs in chronic diseases as whooping cough, Syphilis and glandular fever.
- **Life span:** months to years.

- **T lymphocytes** may be T-killer, T- suppressor, T- helper and T-memory cells.
- **B-lymphocytes:** They are changed into **plasma cells** to secret immunoglobulin (antibodies); other B-cells give B- memory cells.
- **Function:**
  Humoral and cell mediated immunity.

2-Blood monocytes:

-They are about 3-8% of total leucocytes.

-They are large cells (15-20 microns).

-The cytoplasm is non- granular containing large indented **nucleus** and many **lysosomes** containing **acid phosphatase enzyme**.

Functions:

-They leave the blood stream to connective tissue in case of inflammation and change to macrophage cells.

-They phagocytose dead cells and microorganisms.

-They can fuse together to form **giant** cells and **osteoclasts**.

-**Life span** is 3 days in blood stream.

-**Monocytosis** = increase number of monocytes in cases of syphilis, malaria, glandular fever and T.B.

C-Blood platelets:

-They are not true cells but are parts of cells.

-They are small oval non-nucleated bodies, similar to plates.

-They developed from cells in bone marrow called **megakaryocytes**.

-Their number is 250,000- 400.000/ mm^3.

-Their diameter is 2-5 microns.

- **Structures**:

- **By L/M** they show peripheral clear part called **Hyalomere**, and central granular basophilic part called **granulomere** (chromomere).

-**By E/M:**

- The **hyalomere** contains bundles of microtubules and microfilaments.

- The **granulumere** contains:

1- Alpha granules which are lysosomes.

2- Beta granules which are mitochondria.

3- Dense granules which are serotonin, ATP, ADP and calcium.

4- Glycogen granules (in small and large groups).

-**Life span:** 5-10 days.

Functions:

1- Blood agglutination.

2- Blood coagulation.
3- Vasoconstrictor due to release of serotonin substance.
4- Clot retraction.

-Decrease number of **platlets** causes **purpura** in which, the bleeding time is prolonged