General Physiology

For

Technical Students

MED 112

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Overall Aim of the Course

- This course represents the study of general principles of human physiology. The broad goal of teaching physiology is to provide the students a comprehensive knowledge of the normal functions of the organ systems of the body to facilitate an understanding of the physiological basis of health and disease.
- To enable the students to integrate physiological mechanisms with other basic sciences: anatomy, biochemistry, pathophysiology and clinical applications.

Course ILOs

By the end of the course the students should be able to:

1. Define homeostasis.
2. Understand how cells are organized into tissues, organs and systems of the body.
3. Classify and locate the body fluid compartments.
4. Describe structure of the cell and cell membrane and the transport across cell membrane.
5 To identify the different components of the blood.
6 To state the functions of plasma proteins.
7 To correlate synthesis and structure of red blood corpuscles to its functions.
8. To differentiate different types of anemia
9. To describe hemostasis
10. To explain the diagram of coagulation mechanism.
11. To audit the nutritional requirements to avoid anemia and bleeding tendency
12. To differentiate the different types of membrane potentials.
13. To state the steps of neuromuscular transmission
14. To clarify the skeletal muscle contraction
15. To describe the electrical and mechanical properties of cardiac muscle.
16. To describe the main function of blood capillaries
17. To describe normal functions and mechanics of respiration.
18. To point out the pleural layers.
19. To clarify the control of Respiration.
20. To list normal somatic Sensations.
21. To define meiosis and mydriasis.
22. To examine light reflex.
23 To examine visual acuity.
24. To test deafness.
25. To detect normal and abnormal gait.
26. To enumerate functions of the saliva.
27. To describe phases of swallowing.
28. To list gastric secretions and its functions.
29. To list liver functions.

30. To enumerate functions of the kidneys and nephrons.
31. To define filtration, reabsorption and secretion.
32. To summarize mechanism of urine formation.
33. To enumerate the names of sex hormones and its functions.
34. To describe the female ovarian and menstrual cycles.
35. To describe the semen composition.
36. To point out the regulation of body temperature
37. To understand the mechanisms regulating the arterial blood pressure
38. To detect the normal and abnormal values of arterial blood pressure.
39. To understand how to observe some respiratory problems.

Table of content

Introduction

- **Physiology**

Is the study of the function of living things: human, plant, bacterial, viral……etc.

- **Human physiology**

Is the study of the functions of organs and systems and the way those functions are integrated.

- The human body is made of 75-100 trillion cells.
- Cells →→ Tissues →→ Organs →→ Systems
- Collection of **similar cells** with similar properties form **tissues** (e.g. muscular tissue, connective tissue).
- **Different tissues** combine to form **organs** (e.g. heart, brain, liver).
- **Organs** with **complementary functions** constitute the different **systems** (e.g. cardiovascular system, nervous, GIT…)

Body fluids

The body of a normal adult male is composed of about:

- 18 % proteins
- 15% fats
- 7% minerals
- 60% **Water:** → 40% I.C.F
  → 20% E.C.F: → 5 % IVF
  → 15% ISF

- The intracellular fluid compartment (I.C.F.): Is the water inside the cells. It accounts for 2/3 of body water or 40% of body weight.
- The extracellular fluid compartment (E.C.F.): Is the water outside the cells. It accounts for 1/3 of body water or 20% of body weight.
  It is distributed as:
  A) 5% inside vessels called intravascular fluid (IVF), i.e. the plasma.

B) 15% extracellular and outside the vessels bathing the cells called interstitial fluid (ISF).

ECF & ICF

	ICF	ECF	
		Plasma	ISF
Cations (mmol/L)			
Na +	**10**	**145**	**150**
K+	**155**	**4.5**	**4.0**
Ca++	**0.001**	**2.5**	**1.5**
Mg++	**13**	**1.0**	**11.0**
Anions (mmol/L)			
Cl-	**3**	**115**	**110**
HCO3-	**10**	**28**	**27**
HPO3-	**50**	**1**	**1**
Glucose	**1**	**4-6**	**4-6**
Osmolarity (mOsm/L)	**300**	**300**	**300**

- **Homeostasis:**
  Is keeping the internal environment of the cells (of the body) constant.
  The actual environment = the interstitial fluid

- All organs and systems of the body perform functions that help to keep these constant conditions (chemical & physical).

- Cells are capable of living, growing and providing their special functions so long as the proper concentrations of oxygen, carbon dioxide, glucose, the different ions, amino acids and fatty substances are available in this internal environment.

- **Regulating Systems**:

• The functions of the various systems of the body are regulated by the two control systems.

(1) The endocrine system:

It is formed of endocrine glands that secrete hormones in blood. It acts slowly but has a prolonged action.

(2) The nervous system:

It is responsible for rapid regulation of the functions of the various systems of the body.

Overview of the cell

The typical cell consists of:

- The cell membrane.
- The cytoplasm: contains
  - ► Cytosol-fluid: 55% of total cell volume.
  - ► The nucleus.
  - ► Cytoplasmic organelles

The function of each part

	Function (s)
Cell membrane 	● Support ● Protection ● Controls movement of materials in/out of cell ● Barrier between cell and its environment ● Maintains homeostasis
Nucleus 	● Controls cell activities and cell division

Organelle	Function (s)
Mitochondrion 	● Generation of energy (ATP)
Lysosome 	● Contains digestive enzymes ● Breaks down larger food molecules into smaller molecules ● Digests old cell parts
Rough endoplasmic reticulum **due to presence of Ribosomes** 	● Site of glycoprotein & phospholipids synthesis ● Site of protein synthesis
Smooth endoplasmic reticulum	● Site of steroid synthesis, and Ca^{++} storage
Golgi apparatus 	● Processing & Packing of materials as vesicles.

The structure of cell membrane

- Thin plastic and semipermeable membrane,
- Composed mainly of proteins and phospholipids bilayer.

The Lipid bilayer

- Lipid soluble substances (e.g. O2, CO2, steroid hormones) can dissolve in and cross the lipid bilayer.
- Water soluble substances (e.g. Na+, Cl-, water, glucose) cannot dissolve in lipid bilayer, they cross through water-filled channels or pores or transported by carrier

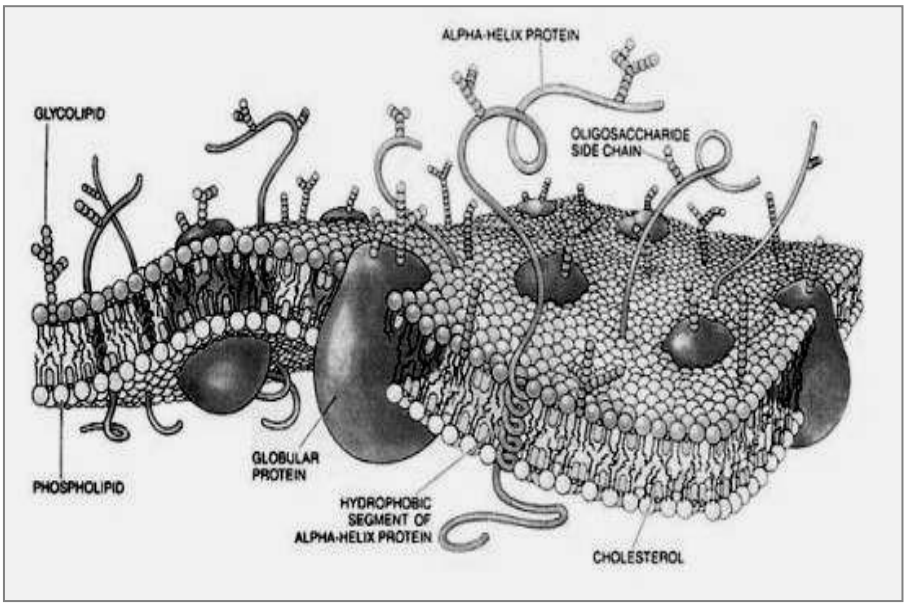
Functions of membrane proteins:

1) Ion channels: Have a pore through which specific electrically charged ions can flow in & out of the cell.

2) Transporters (Carriers).

3) Receptor: e.g. for hormones.

4) Enzymes



Transport across the plasma membrane

I) Diffusion

- Types of diffusion
  - Simple diffusion: passive (needs no energy), from high concentration to low concentration of water, no carrier is used.
  - Osmosis: for water
  - Facilitated diffusion: passive (needs no energy), from high concentration to low concentration of water, needs carrier

II) Active transport:

- Occurs against concentration gradient (from low concentration to high concentration)
- Needs carrier
- energy (ATP) is used

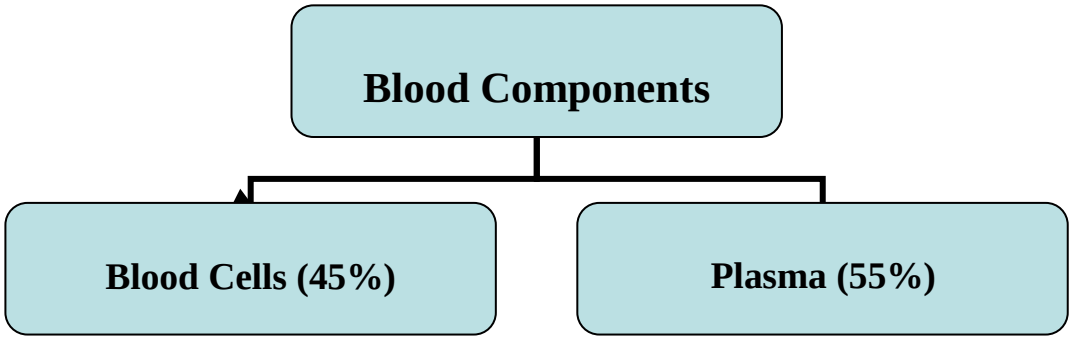
III) Transport in vesicles (Endocytosis, exocytosis, transcytosis)

Blood

Blood is a vital fluid which circulates within cardiovascular system. Its volume is about 5 liters (5000 ml) in adult.

Blood functions:

- Transport function: O2 & CO2 – glucose-metabolic end products as urea- hormones and vitamins.
- Defensive function: White blood cells attack invading pathogenic organisms and produce antibodies.
- Hemostatic function: Stoppage of bleeding when blood vessel is injured by clotting mechanism.
- Homeostatic function: blood keeps internal environment constant for optimum function of cell. e.g regulation of pH & thermoregulation.



- **Red blood corpuscles** RBCs(5 millions/mm³)
- **White blood cells** WBCs(4000- 11000/mm³)
- **Platelets (thrombocytes)** (250000/mm³)

• Is a yellow clear fluid that contains
- Water
- Organic substances: Plasma proteins, Plasma lipids and others (glucose, amino acids vitamins, enzymes and waste products).
- Inorganic substances: Sodium, Chloride, Potassium, Bicarbonate, Phosphate.
- Gases: CO_2, O_2

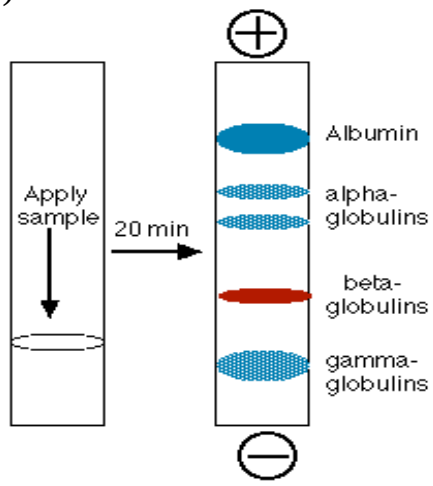
Serum:

- When blood is allowed to clot then centrifuged we get serum instead of plasma.
- Serum= Plasma – clotting factors

Plasma proteins

Has three main groups

- Albumin (60%)
- Globulins (36%)
- Fibrinogen (4%)



Separating serum proteins by electrophoresis

A) Albumin:

Most abundant plasma protein (60 %)

1- Contributes to plasma osmotic pressure (Osmotic regulator) to maintain blood volume

2- Carrier protein :

a- Transport lipid and steroid hormones.

b- Binds minerals like Ca+2

- Produced by : Liver
- Deficiency may be caused by: liver and kidney diseases
  This will lead to: Edema, Ascitis

B) Globulins (36%):

Types :

i- Alpha (α) and β globulins : Are produced by : the liver, act as .

- Carrier substances : Transport metal ions, hormones and lipids.
- Role in hemostasis : Function as clotting factors.

ii- Gamma (γ) globulins : γ- globulins are antibodies, are produced by B-lymphocytes during the immune response.

C- Fibrinogen (4%):

- A soluble circulating plasma protein
- Produced by the liver.
- Converted into a blood clot.
- Responsible for blood viscosity.

Erythrocytes (Red Blood Corpuscles, RBCs)

- **Count:** 4.8 – 5.4 million/ mm^3.
  ♀ ♂
- **Size:** 7μ in diameter.
- **Volume** is 90 μm^3
- **Shape:** Biconcave non- nucleated. The biconcave shape provides large surface area to help gas exchange & enhances cell flexibility.
- **Life span:** 120 days.

- **Destruction and fate:** The old RBCs are destroyed in the liver and spleen.
  Hb is liberated and splits → into globin + heme
  The heme part loses iron and is transformed into bile pigments (bilirubin) which pass to the blood.

- **Structure:**

- RBCs are surrounded with an plastic semipermeable membrane
- It contains hemoglobin (34% of its weight).
- There are no mitochondria, so derive energy from anaerobic glycolysis.

Hemoglobin (Hb):

» It is red pigment which carries oxygen.

- **Hb content:**

- 15 -16 gm/dl in adult male.
- 13 -14 gm/dl in adult females.
- 19 gm/dl in newly born infant.

- **Functions of Hb:**

  1. Carriage of O2 & CO2
     - Hb + O2 ⇆ Oxyhemoglobin. (Main)
     - Hb + CO2 ⇆ carbamino hemoglobin.

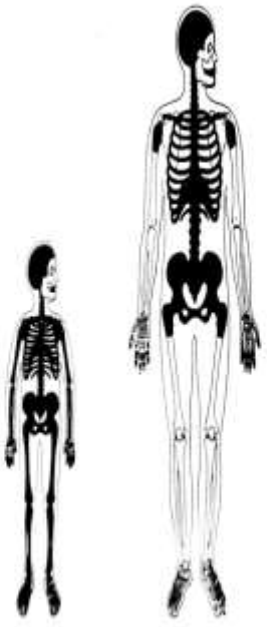
  2. Strong buffer system.

- **Structure of Hb:**

Hemoglobin is made 4 polypeptide chains (globin) and heme thatcontains iron is in the ferrous state (Fe^{2+}) that binds O2.

Erythropoiesis

- **Definition:** It is the process of formation of new RBCs.
- **Sites of Erythropoiesis:**
  - → Liver & spleen in fetus.
  - → Bone marrow of all bone in children (Flat and long).
  - → Flat bones (e.g. sternum, pelvic bones, ribs) and ends of long bone in adults.



Factors affecting erythropoiesis:

1. Oxygen supply to the tissues.
2. Healthy Liver.
3. Healthy Kidney.
4. Healthy bone marrow.
5. Hormones.
6. Diet.

(1) Oxygen supply to the tissues:

Decreased tissue oxygenation (hypoxia) stimulates RBCs formation.
Causes of hypoxia:

- Physiological → - Decreased oxygen tension as in high altitudes.
  → - Increased oxygen demand as in athletes.

- Pathological: → - Hemorrhage (loss of erythrocytes)
  → - Heart failure.
  → - Lung diseases.

Hypoxia stimulates RBCs formation from bone marrow by increasing erythropoietin production.

Erythropoietin hormone

- It is a hormone – glycoprotein in nature.
- **Sources:** → 85% is formed by kidney.
  → 15% is formed by liver.
- Stem cells have specific receptors for erythropoietin which helps the development of stem cells into mature RBCs.

(2) Healthy liver: → Formation of globin part & 15% of erythropoietin
→ Store of iron & vitamin B12.

(3) Healthy kidney: → Formation of 85% of erythropoietin

(4) Healthy bone marrow: → formation of RBCs.

(5) Hormones:
- Specific: erythropoietin acts locally on bone marrow.
- Non specific: Thyroid hormones, Androgen and Cortisol.

(6) Diet: Vitamins: Vitamin B12, folic acid, Vitamin C
Metals: iron & cobalt.
Protein of high biological value.

Vitamin B12 (Cyanocobalamine)

* **Functions:**

1- Essential for DNA synthesis, cell division & maturation of cells (RBCs).
2- Helps formation of myelin sheath of nerves, its deficiency gives neurological manifestation.

* **Storage:** in liver
* **Absorption:** from the lower ileum. Its absorption needs the intrinsic factor that's secreted from mucosa of the stomach..
* **Sources:** Animal origin e.g. liver, meat.

Anemia

- Anemia is a decrease in number of RBCs, hemoglobin content or both.
- Anemia is considered when RBCs count → < 4.5 million in males & < 3.9 millions in females

& Hb content → < 13.0 gm % in males.
< 11.5 gm % in females.

Blood indices

1- Mean corpuscular Hb (MCH) = amount of Hb in single RBC = 30 pg

2- Mean corpuscular Volume (MCV) = Volume of single RBC = 90 cμ

Anemia is classified according to blood indices into:
1- Normocytic normochromic anemia: i.e normal blood indices.
2- Microcytic hypochromic anemia : i.e. lower blood indices.
3- Macrocytic normochromic : i.e. higher blood indices.

Normocytic Normochromic anemia (80< MCV <100 cμ)

Causes:

a) **Aplastic anemia:** decrease RBCs synthesis due to bone marrow inhibition by → antibiotic, malignancy, irradiation.
b) **Hemolytic anemia:** Excessive hemolysis of RBCs due to:

1- Intrinsic disorders of RBCs:

► Membrane disorders: e.g. Congenital Spherocytosis where cells are spherical, small & fragile.
► Hemoglobin disorders: e.g. Sickle cell anemia and thalassemia
► Enzyme disorders: e.g. deficiency of glucose-6-phosphate dehydrogenase which defend of RBCs against oxidants (as in favism).

2) Extrinsic disorders:

► Antibody causing hemolysis (Rh incompatibility).

► Bacterial toxins .
► Chemicals e.g. benzene derivatives.
► Drugs e.g. anticonvulsant & antimalarial.

c) Acute blood loss (acute hemorrhage).

Microcytic Hypochromic anemia (MCV < 80 cμ)

- Small RBCs with low Hb content inside caused by iron deficiency.
- Causes of iron deficiency anemia:

A) Decreased dietary intake especially in children and pregnancy.

B) Decreased iron absorption:
- Gastrectomy (HCl is absent).
- Small intestinal diseases.
- Vitamin C deficiency.
- Increase phosphate and phytate as they form insoluble salts with iron.

C) Chronic blood loss: as in piles, bleeding peptic ulcer and ankylostoma infection.

N.B. Tae decrease iron absorption because it contains tannic acid & theophyline.

Macrocytic anemia (MCV >100 cμ)

- It is due to deficiency of vitamin B12 or folic acid → decrease DNA synthesis → decrease proliferation and differentiation of erythroblasts → megalocytes or macrocytes that are fragile.

- **Causes of folic acid deficiency:**

- Decrease intake in diet.
- Increase demands as in pregnancy.
- Deficient absorption as in intestinal diseases.
- Antifolate drugs used in treatment of cancer.

- **Causes of vitamin B12 deficiency:**

- Deficient absorption as in intestinal diseases & after gastrectomy due

to absence of intrinsic factor.
- Liver diseases.
- Deficiency of vitamin B12 in diet which is rare.

Polycythemia

- Abnormal increase in the RBC.
- Increases blood viscosity ⇨ heart failure

Platelets (Thrombocytes)

- **Count:** Average 250.000/mm^3 (150.000-400.000)
- **Origin:** in bone marrow
- **Distribution:** 70 % in blood & 30 % in spleen
- **Platelets functions**
  When a blood vessel is injured, platelets form a mechanical plug.

Hemostasis

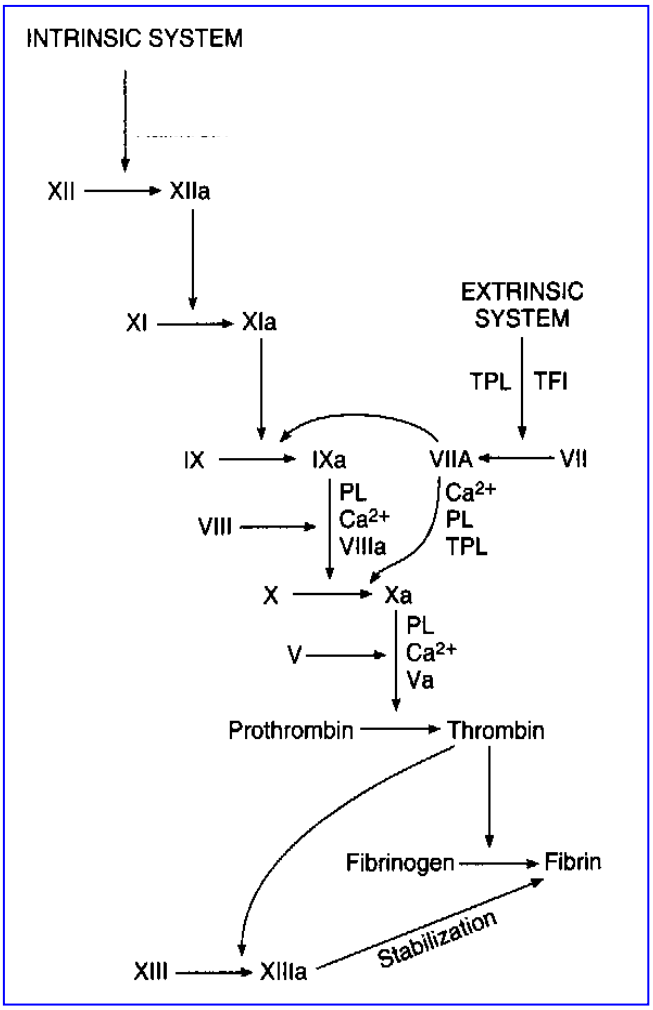
- Is the stopping of bleeding from the walls of a damaged blood vessel.
- Hemostasis mechanisms:
  - Vasoconstriction (V.C)
  - Platelets reactions (Platelet Plug)
  - Coagulation mechanism (Clot formation)

- Aspirin inhibits platelets aggregation.

Blood Coagulation (= Blood Clotting)

- Blood clot = fibrin network entangling the blood cells

Blood coagulation is brought about by clotting factors, which are plasma proteins, mostly (β-globulins). They are proteolytic enzymes, which are present in blood in an inactive form. When activated, they activate other inactive enzymes, resulting in a cascade of reactions, which end in clot formation. To simplify the description of the clotting mechanisms, clotting factors were given numbers (I-XIII, no VI). They are given an "a" when they are activated.



Abnormalities of hemostasis

1. **Thrombocytopenic purpura**
   - Decreased platelet count (below 50 000/mm3)
   - Subcutaneous hemorrhage
   - Prolonged bleeding time
2. **Vitamin k deficiency & liver diseases**
   - Vit.. K is important in formation of factors II,VII, ,IX, X in the liver
   - It is a fat soluble vitamin & is formed by intestinal flora
   - Its absorption is decreased in obstruction of bile duct
   - It is deficient in case of severe liver disease, abuse of antibiotics and newborn.

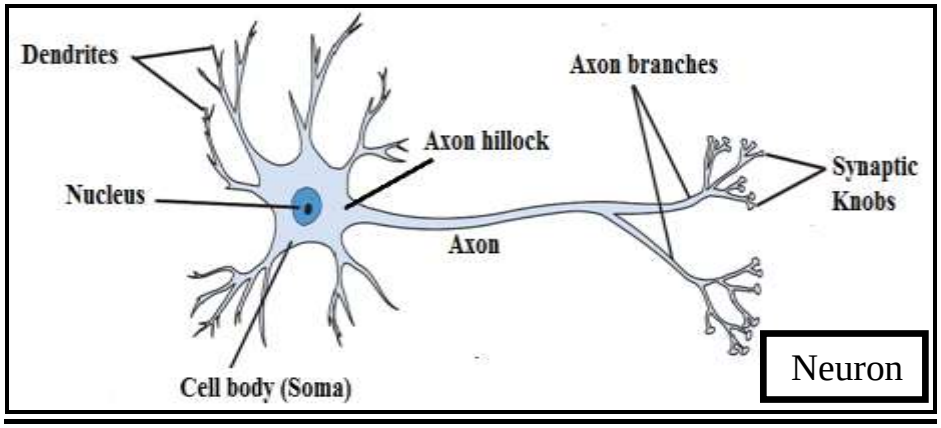
3. Hemophilia

- Congenital recessive sex-linked disease transmitted by females to males
- Characterized by severe bleeding after trauma
- It is due to absence of factor VIII (hemophilia A) or IX (hemophilia B) or XI (hemophilia C)

Nerve and Muscle

The Nerve

- The function of nerves is to carry messages to and from the central nervous system.
- The unit structure of nervous system is neuron.
- The neuron is formed of cell body & cell processes (dendrites & axons).
- Two types of axons (nerve fibers) are found:
  - Myelinated nerve fibers.
  - Non-myelinated nerve fibers.



Excitability:

- It is the ability of living tissues to respond to changes in the environment (stimuli).
- The most excitable tissues in the body are nerves and muscles.

Membrane Potential:

- **Membrane potential:** Charge difference between the inside and outside of the membrane.
- The charge difference is due to the difference of concentrations of ions on either side of the cell membrane.

- Types of membrane potential
  1- Resting membrane potential: un-stimulated nerve.
  2- Action potential (nerve impulse): due to stimulation of nerve.

The Resting membrane Potential (RMP)

- Inside the membrane is negative and the outside is positive
- RMP = -90 mv in large nerve fiber and SK. Muscle fiber.
  = -70 mv in nerve fiber& medium sized muscle fibers.
  = -20 to -40 mv in RBCs and epithelial cells

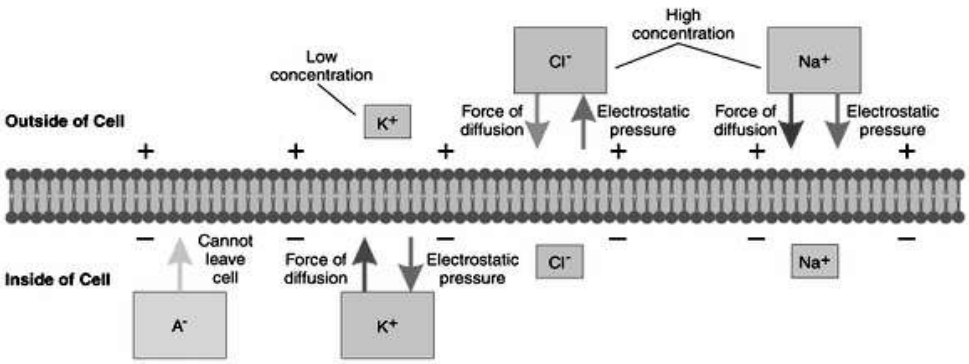
Causes of the resting membrane potential:

- Is due to unequal distribution of ions on both sides of the cell membrane. There are more Na^+ ions in the extracellular fluid and more K^+ ions in the intracellular fluid.

- In nerve and muscles it is determined mainly by 2 mechanisms:

(1) Selective permeability of membranes: The membrane is more permeable to K^+ which leaks out to the outside of the membrane giving it a positive charge. Permeability to K^+ is 20-100 times greater than Na^+.
The membrane is impermeable to negatively- charged proteins which is trapped inside the cells.

(2) The sodium/potassium ATPase pump: This pump pushes only two potassium ions ($2K^+$) into the cell for every three sodium ions ($3Na^+$) out.



Action potential

- Is the rapid change in the membrane potential due to stimulation of a nerve fiber by a adequate stimulus.
- Action potential is also called a nerve impulse.

- **Phases and shape:**
  1) Latent period.
  2) Depolarization phase.
  3) Repolarization phase.
  4) Hyperpolarization phase

- **Latent period:**
  Is the interval between stimulus application & start of the action potential.

- **Depolarization phase:**
  Membrane potential decreases slowly from – 90 mV to – 65mv (firing level) then become rapid until it overshoots the isopotential and reach + 35mV

- **Repolarization phase:**
  - Membrane potential returns to resting level
  - It starts rapidly then slows down

- **Hyperpolarization phase:**
  The membrane potential overshoots in opposite direction to form small prolonged hyperpolarization then RMP is reached gradually.

Ionic basis of action potential:

Depolarization:

- Is produced by Na+ entry through voltage gated Na + channels:

- Electric stimulation opens some voltage gated Na + channels, flow of Na + causes more depolarization & more opening of Na channels till membrane potential reach -65 mv (firing level), then all Na channels are opened.

During Repolarization:

A- Inactivation of Na + channels.

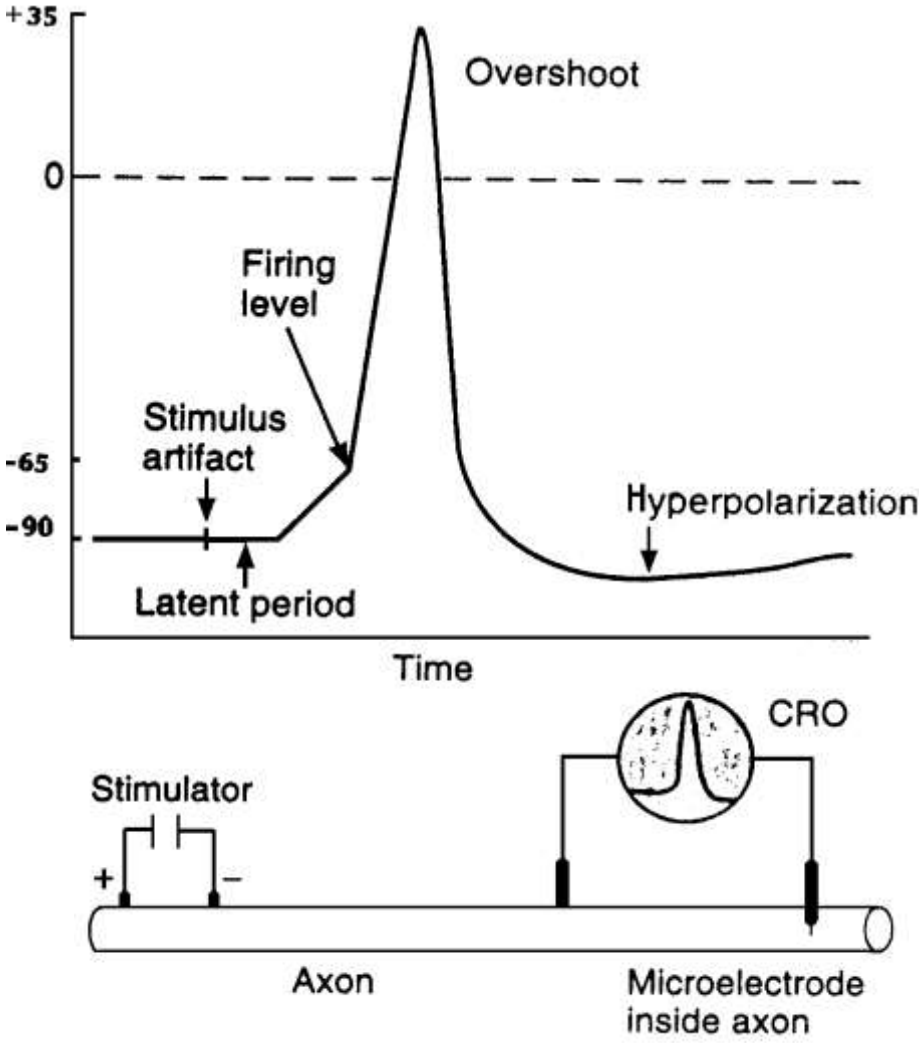
B- Activation of K + channels: → K + Outflow through voltage-gated K + channels).

Hyperpolarization:

Is caused by slow closing of K+ allowing K + exit more than needed.

Re-establishing Na + & K + gradients after action potential:

by the action of Na + - K + pump in exactly same way of RMP.



- This wave of depolarization followed by a wave of repolarization (an action potential or a nerve impulse) travels the length of a nerve axon, and it is how the nervous system communicates.

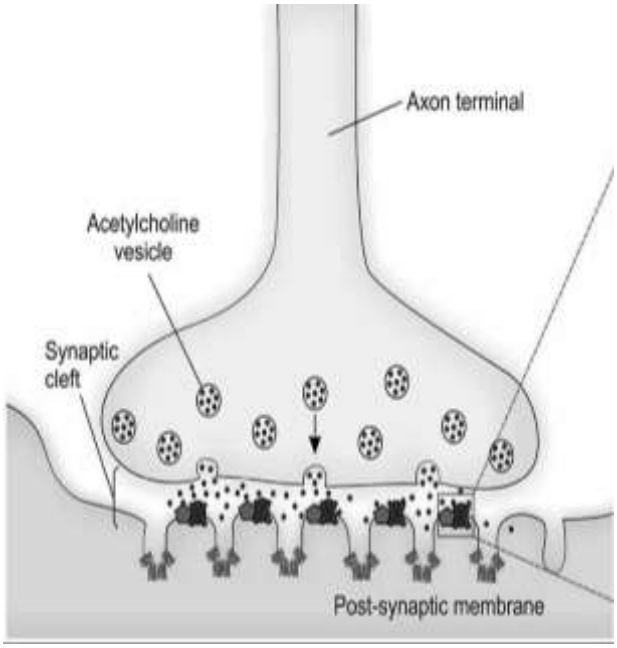
Neuromuscular Junction

Neuromuscular Transmission

This means transmission of impulses from motor nerve fiber to skeletal muscle fiber.

Physiologic Anatomy of Neuromuscular Junction:

The motor nerve fiber branches as it approaches the muscle, sending axon terminals to several skeletal muscle fibers. Each skeletal muscle fiber receives only one axon terminal containing acetylcholine (Ach) vesicles. The nerve ending fits into depression in the muscle membrane.
Underneath the nerve endings the muscle membrane is thickened and called motor end plate (MEP) which is rich in Ach receptors.



Neuromuscular transmission:

- When an action potential travels down a motor nerve and reaches the nerve terminal, acetylcholine (ACh) molecules are released from the presynaptic vesicles and adhere to acetylcholine receptor (AChR) at the postsynaptic folds.

- Channels in the AChR open, allowing Na+ and other cations to enter into the muscle fiber endplate and depolarize it.

- The multiple depolarizations will sum up, and if large enough, trigger an action potential, which travels along the muscle fiber to produce contraction.

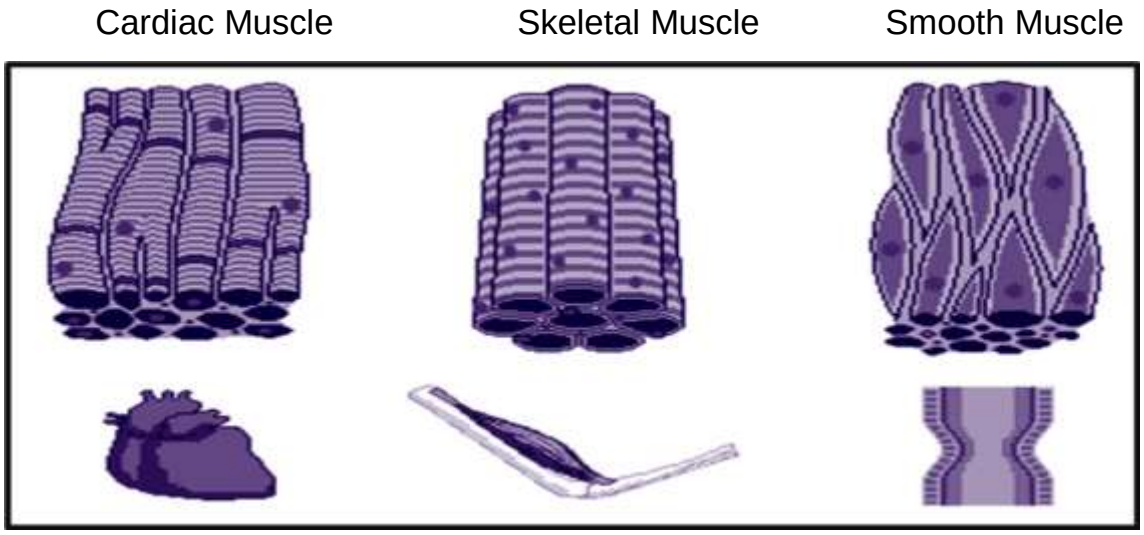
Properties of Neuromuscular Transmission

- It **is unidirectional** i.e. it occurs in one direction only from the nerve to the muscle.

- There **is a delay** of about **0.5 msec**. It represents the time needed for the release of A Ch, change in the permeability of muscle fiber membrane, inflow of Na+ and building up of depolarization to the firing level.

- Easily **fatigued as** a result of repeated stimulation and exhaustion of A Ch vesicles.

Muscles



Skeletal muscles

- More than 400 skeletal muscles.

Functions of skeletal muscles:

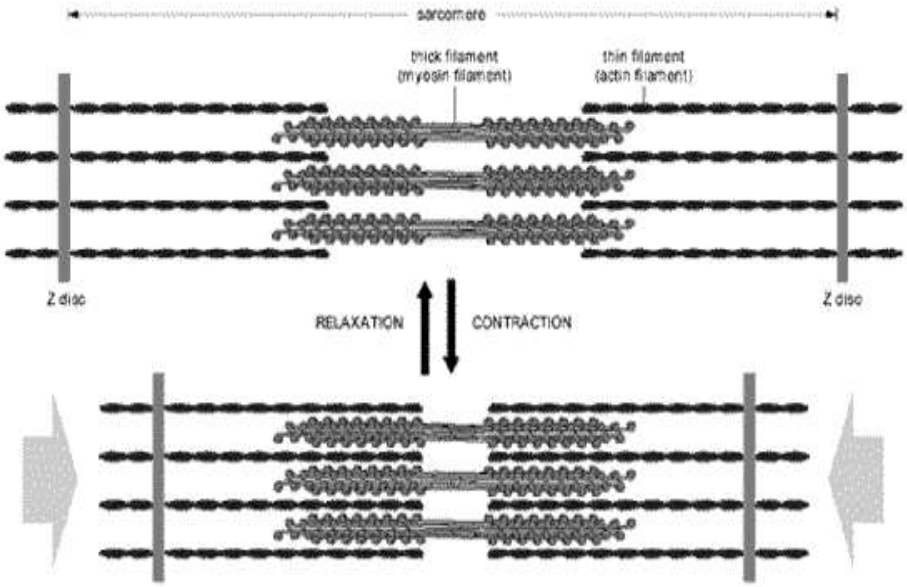
- Locomotion
- Breathing
- Helps venous & lymphatic return
- Keeping body posture
- Heat production

Structure of skeletal muscle:

- Fascicles (bundles of individual muscle fibers)
- Muscle fibers = muscle cells
- Myofibrils
- Myofilaments (actin – Myosin)

<u>Mechanism of muscle contraction:</u>

- Contraction is initiated by action potential.
- Ca++ is released from the sarcoplasmic reticulum.
- Sliding actin over myosin and generation of tension (force).
- Relaxation



Types of skeletal muscle contraction:

(1) Isometric contraction:

- ► The muscle length remain constant
- ► Tension increases.
- ► No external work done.

(2) Isotonic contraction:

- ► The muscle length decreases.
- ► Tension remains constant.
- ► External Work is done.

<u>Muscle Fatigue</u>: due to:

- Accumulation of metabolites, such as lactic acid
- Depletion of muscle ATP
- Diminished transmission at neuromuscular junction

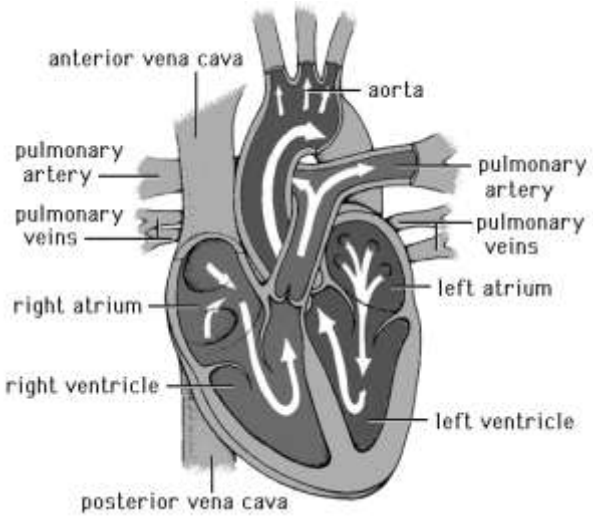
Cardiovascular System (CVS)

- The main function of the cardiovascular system is to ensure adequate blood supply for all organs of the body for optimal cellular activities.

- The cardiovascular system is composed of:
  1) The heart: "Central pump"
  2) Closed system of blood vessels (arteries, veins, arterioles, venules, blood capillaries)

- Systole: cardiac (ventricular) contraction to eject blood.

- Diastole: cardiac (ventricular) relaxation to be filled with blood.



Cardiac Properties

[1] Excitability (Action Potential)

[2] Rhythmicity = Automaticity "Pacemaker potential"

[3] Contractility

[4] Conductivity (Spread of cardiac excitation)

[1] Excitability (Action Potential)

- The resting membrane potential of cardiac muscle is -90 mv due to selective permeability of membrane & Na^+ - K^+ pump.

- **The action potential** is composed of:

A. Depolarization
B. Repolarization

A- Depolarization: Rapid depolarization from resting membrane potential with overshoot to + 20 mv due to opening of voltage gated fast Na+ channels and Na+ influx.

B- Repolarization: **W**hich is slow & **triphasic:**

(1) Phase 1: small & fast due to:
- Sudden closure of fast Na^+ channels.
- Opening of chloride channels leading to influx of Cl^- .

(2) Phase 2: The Plateau which is **unique property**
- It is due to balance between Ca^{++} inflow & K^+ outflow where the membrane potential is near zero.

(3) Phase 3: Rapid repolarization to RMP due to:
- Closure of Ca^{++} channels → Ca^{++} inflow stops.
- The outflow of K^+.

- The efflux of K^+ continues until repolarization is complete & return to RMP.

[2] Rhythmicity: Automaticity

- **Definition** of Rhythmicity: It is the ability of heart to beat regularly and initiate its own regular impulses independent on nerve supply. It is a myogenic character.

- It is done by **automatic cells** present at 3 sites:

- **Sinoatrial node (SAN)** which discharges at a rate of 90 impulses/min.

- **Atrioventricular node (AVN)** which discharges at a rate of 60 impulses/min

- **Purkinje fibers** which discharge at a rate of 30 impulses/min

- **SAN is the most rapid, so, it is the normal pacemaker.**

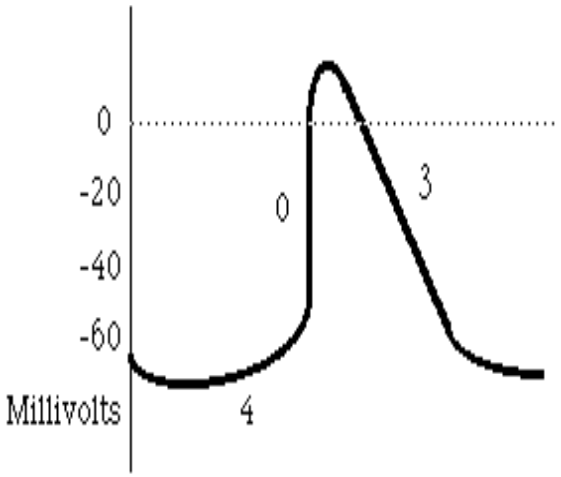
- The heart rate is about 70 beats/min. at rest, while SA Node rhythm is 90/min. This is explained by tonic vagal discharge **"Vagal tone" to the SAN** during rest.

- **Automatic cells differ from ordinary cardiac muscle fibers :**

1) They have **unstable** membrane potential**.**
No resting membrane potential (RMP).

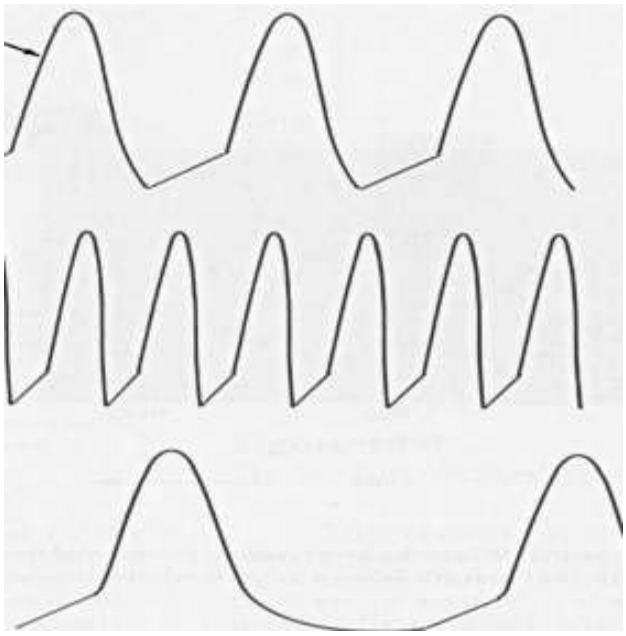
2) They have membrane potential **= - 60 mv (not -90 mv).**

3) They have **no plateau** in their action potential.



- **Factors decrease rhythmicity (heart rate):**
  1) Vagal stimulation
  2) Acetylcholine
- They decrease the heart rate (**bradycardia**).

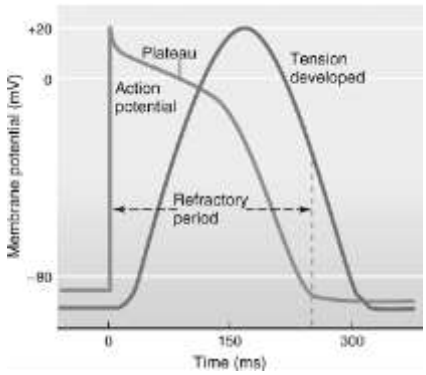
- **Factors increase rhythmicity(heart rate):**
  1) Sympathetic stimulation
  2) Noradrenaline
  3) High temperature.
- They increase heart rate **(tachycardia)**.



[3] Contractility

- **Contraction (Systole)** begins just after the beginning of action potential

- **Diastole** begins with the rapid phase of repolarization (phase 3).



Factors affect cardiac contractility:

- Initial length of muscle fibers (starling law)
- Inotropic state.

Starling Law:

- "Within limits, the more the initial length of muscle fibers, the more will be the force of contraction".

- Physiologically: The initial length of the ventricular muscle fibers is determined by the amount of blood (venous return) which fills the ventricles at the end of diastole.

The inotropic state "Contractility"

Positive inotropic factors (Increase contractility)

1) Sympathetic or norepinephrine
2) Xanthines such as caffeine & theophyline
3) Glucagon hormone
4) Digitalis (plant alkaloid extract)
5) lncreases in extracellular Ca^{++} stops heart in systole

Negative inotropic factors (decrease contractility)

1) Parasympathetic or Acetyl choline
2) Calcium antagonists & anesthetics
3) Ischemia
4) Heart failure
5) Removal of Ca^{++} from ECF stops heart in diastole

[4] Conductivity (Spread of cardiac excitation)

- **Definition:**
  It is the ability of the cardiac muscle to transmit or conduct the cardiac impulse.

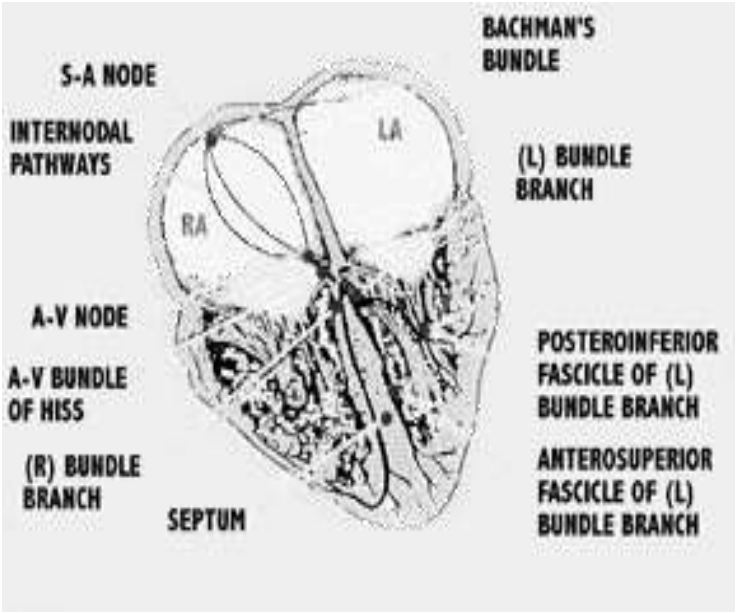
- Impulses generated in the SA-node pass through the atrial pathway (internodal pathways) to the AV-node to AV bundle & via the Purkinje system to ventricular muscle.

AVN = 0.05 m/sec = AV- nodal delay

- This is very slow rate which is known as AV-nodal delay. It is of great significance:
  1- It gives a chance for both atria to be excited and to contract to empty their blood into ventricles before ventricular systole begins.
  2- It protects the ventricles against atrial high rhythms.

Purkinje system = 4m/sec

- It has the highest speed of conduction
- This is a very fast rate to conduct nerve impulses to both ventricles in a very short time and at the same time → Both ventricles contract together as one unit leading to powerful pumping.



Cardiac Output (CO)

- Is the volume of blood pumped by each ventricle per minute .
  CO = stroke volume X heart rate = 5 L/min
  CO = SV X HR
  = 70 X 70 = 5 L/min

- **Stroke volume** SV: is the volume of blood pumped by each ventricle per beat = 70 ml.

- **SV** = End diastolic volume - End systolic volume
  = EDV - ESV
  = 135 - 65 = 70 ml.

- **EDV:** is the volume of blood remained inside the ventricle at end of diastole.

- **ESV:** is the volume of blood remained inside the ventricle at end of systole.

Arterial Blood Pressure (ABP)

Definitions:

- **Arterial blood pressure (ABP):** it is the pressure of blood on arterial wall.

- **Systolic pressure (SP):** it is the maximum pressure reached within the arteries during ventricular systole 120 mmHg (90 -140).

- **Diastolic pressure (DP):** it is the minimum pressure reached within the arteries during ventricular diastole just before ventricular ejection 70 mmHg (60 - 90).

- **Pulse pressure:** = Systolic pressure - diastolic pressure = average 50 mmHg.

Physiological Variations in ABP

1 -Age: ABP increases with age due to loss of elasticity of arteries

2-Sex: Below 45 y female have less ABP than male
Above 45 y the pressure increases in female due to hormonal changes.

3-Race: Europeans + Americans > Orientals due to: stress & high cholesterol in diet.

4-Emotions: sympathetic stimulation —> Increase ABP especially SP.

5-Exercise: increases SP and decreases DP.

6-Gravity: each 1 cm below heart increases ABP by 0.77 mmHg. each 1 cm above the heart decreases ABP by 0.77 mmHG.

7-Respiration: Small fluctuations of ABP during respiration.

Factors which determine ABP & Pulse pressure

- ABP = CO X TPR.
  ABP = SV X HR X TPR.

- Stroke volume (SV): Increase in SV—> increases SP more than DP

- Heart rate (HR): Increase in HR —> increases DP

- Total peripheral resistance (TPR):
  Increase TPR —> increase DP more than SP
  TPR depends on the diameter of blood vessels.

- Elasticity of aorta + arteries: Atherosclerosis —> increases SP & decreases DP

Regulation of Arterial Blood Pressure (ABP)

ABP is regulated by **3 mechanisms:**

I - Nervous mechanism:

- This is the **Rapid** mechanism.

II- Capillary Fluid Shift mechanism:

This is the **intermediate** mechanism.

Ill- Role of Kidney = Hormonal regulation of ABP

- This is the **slow** mechanism.

I - Nervous mechanism:

- This is the Rapid mechanism.

- Decreased blood pressure leads to Sympathetic stimulation → vasoconstriction, increase in SV & increase in HR → Increases ABP.

- Increased blood pressure leads to Parasympathetic stimulation → vasodilatation and decrease in HR → Decreases ABP.

II- Capillary Fluid Shift mechanism

- This is the intermediate mechanism.

- Increase blood volume —> **increase ABP** —> increase capillary hydrostatic pressure —> increase filtration of fluid from plasma to the tissue fluid —> decrease plasma volume —> **decrease ABP.**

- Decrease blood volume —> **decrease ABP** —> decrease capillary hydrostatic pressure —> decrease filtration of fluid at arteriolar end of capillaries + increase reabsorption at venular end —> increase plasma volume —> **increase ABP.**

lll- Role of Kidney = Hormonal regulation of ABP

- This is the slow mechanism
- Kidney regulates ABP by regulating plasma volume (and extracellular fluid volume)
- **It** is the **most important** mechanism for ABP regulation.

If ABP decreases —> It is increased by 2 mechanisms:

A) Secretion of ADH and aldosterone hormones:

Decrease ABP —> decrease blood volume —> increase secretion of aldosterone & ADH —> salt & H_2O retention —> increase extracellular fluid volume —> increase venous return —> increase cardiac output —> increase ABP.

B) Renin - Angiotensin system:

Decrease ABP —> renal ischemia —> renin release.

Renin ACE

Angiotensinogen → Angiotensin I → Angiotensin II → vasoconstriction and aldosterone secretion leading to salt and ater retention and increased arterial blood pressure

- **Renin hormone is secreted from the kidney**
- **Angiotensinogen protein is formed by the liver.**
- **Angiotensin converting enzyme (ACE) is secreted by the blood vessels of the lungs.**

Capillary Circulation

- The exchange of materials across capillary wall leads to equilibrium between the blood and interstitial fluids. This exchange occurs by:
  1. Diffusion
  2. Filtration = Bulk Flow

1- Diffusion:

- It is passive
- Occurs in both directions
- Concerned with H_2O and dissolved substances

Factors affecting diffusion rate:

[A] Factors in substance:

1- Concentration difference: diffusion rate ∝ concentration difference

2- Solubility:

a) H_2O soluble and lipid insoluble ➔ diffuse through the pores.

b) Lipid soluble diffuses through pores and cell membrane.

3- Molecular weight (M.W.):

a) M.W. < 5000 ➔ Easy diffusion, e.g. H_2O. NaCl, Glucose.

b) M.W. > 5000 ➔ progressive difficulty.

[B] Factors in capillary wall permeability:

1- Liver capillaries:

Have large wall fenestrations ➔ high permeability.

2- Muscle, skin, heart and lung capillaries:

Has no wall fenestrations ➔ low permeability.

3- Kidney, intestine capillaries:

Has thin fenestrated wall ➔ moderate permeability.

2- Filtration = Bulk flow: across capillary wall.

- It is passive.
- Occurs in one direction.
- It is the bulk transport of H_2O and electrolytes.

Factors affecting filtration:

A] Mean forces tending to move fluid outwards:

1- Hydrostatic capillary pressure = 37 mmHg at arterial end.
= 17 mmHg at venous end.

2- Interstitial fluid colloidal osmotic pressure (O.P.) = 0 mmHg

B] Mean forces tending to move fluid inwards:

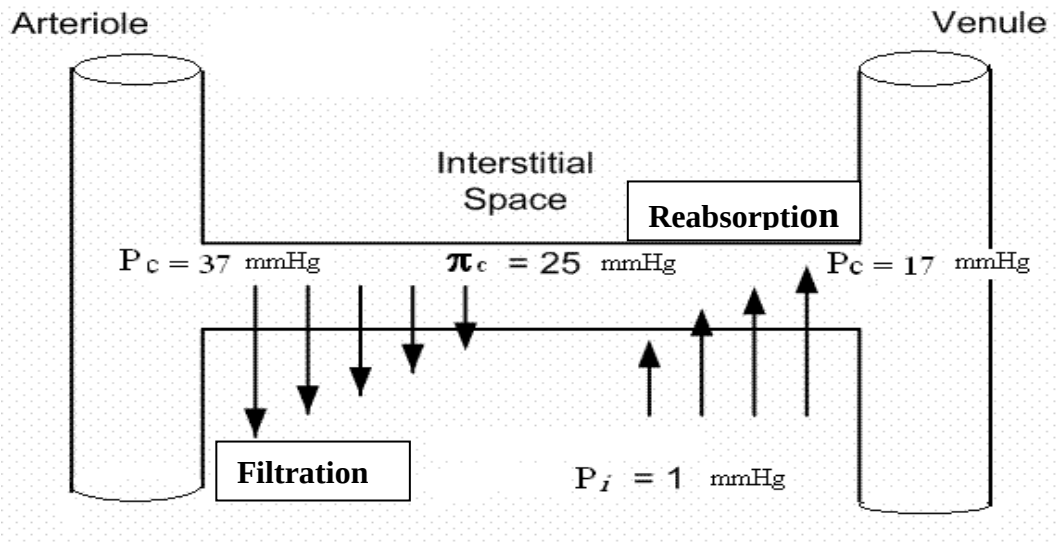
1- Colloidal O.P. of plasma proteins = 25 mmHg (mainly due to albumin).

2- Hydrostatic pressure of interstitial fluid = 1 mmHg.

Summation of mean forces:

1- At arteriolar end = 11 mmHg outwards ➔ filtration of fluid from blood to the interstitial fluid as a bulk.

2- At venular end = 9 mmHg inwards ➔ reabsorption of a nearly equal amount of fluid into blood (the remaining is taken by lymphatics).



Pc=capillary hydrostatic pressure
πc=capillary osmotic pressure
Pi = hydrostatic tissue pressure

Respiration

Respiratory Passages:

- Nose or mouth
- Pharynx
- Larynx and associated structures
- Trachea
- Right and Left main bronchi
- Bronchi and bronchioles
- Lung alveoli

The function of respiration is to:

- Supply oxygen, remove carbon dioxide
- Regulate the pH
- Excretion of certain anesthetics drugs.

Non respiratory functions of the lungs:

1) Regulation of acid-base balance
2) Defense against pathogens
3) Water & heat loss
4) Enhancing venous return
5) Enhancing vocalization
6) Activating certain plasma proteins

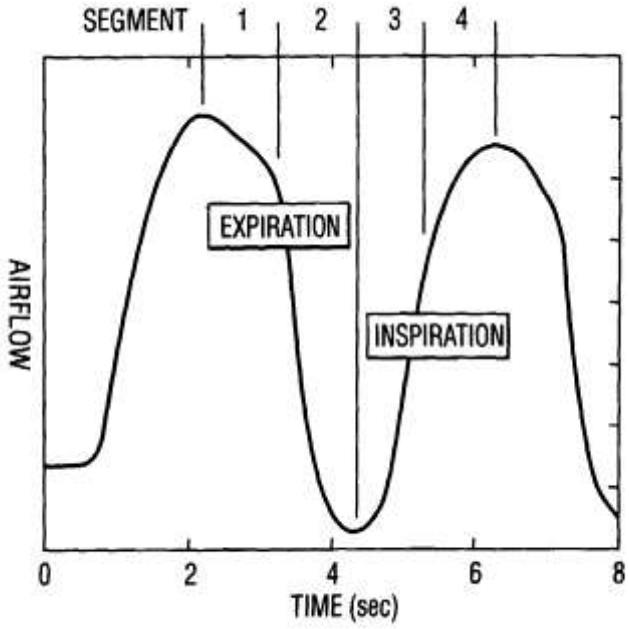
Mechanics of respiration

- **Each respiratory cycle is composed of:**
  A- Inspiration **B- Expiration**

Respiratory cycle

- Consists of inspiratory and expiratory phases with a pause inbetween

- Normal resting respiratory rate (cycles) in adults:
  12 – 16 cycle/min., it is double in children

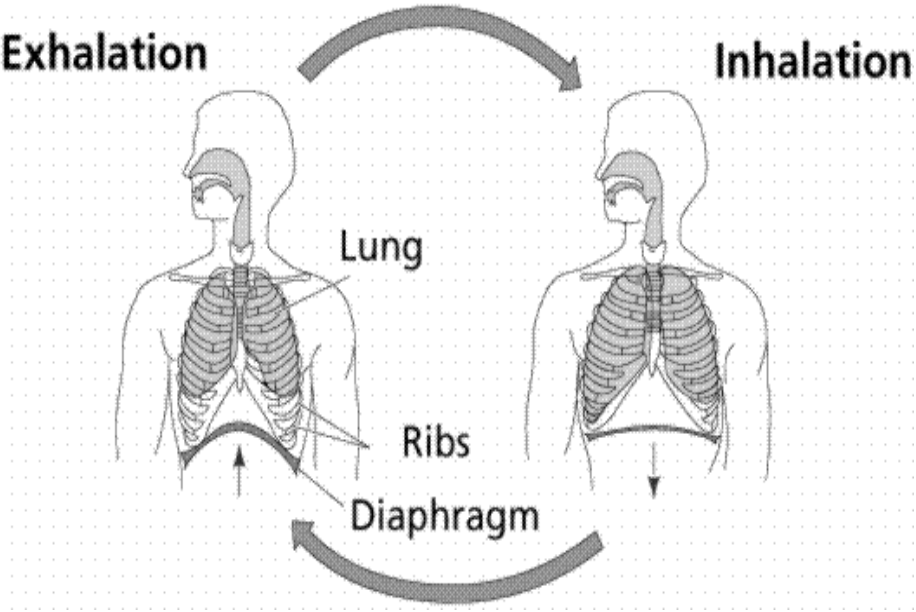


Inspiration

- Active process
  - Contraction of diaphragm & external intercostals muscles → increase all chest dimensions
- Increase volumes of the lungs (lung inflation) & thorax
- Decrease intra-thoracic pressure & intra-alveolar pressures
- Air rushes in

Expiration

- Normally it is passive
- It is due to elastic recoil of lungs & chest wall
- Decrease volumes of the lungs (lung deflation) & thorax
- increase intra-thoracic pressure &intra-alveolar pressure
- Air forces out
- Expiration become active during forced expiration and bronchial obstruction (due to internal intercostals, abdominal muscles contraction)



Respiratory Pressures

[1] Alveolar pressure
[2] Intrapleural pressure
[3] Trans-pulmonary pressure

[1] Alveolar pressure

- It is the pressure inside the alveoli during respiratory cycle.
- When glottis is open, the pressure in all parts of respiratory tract up to alveoli equal to atmospheric pressure (atmospheric pressure = 760 mmHg). So no air flows into lung.
- During normal **inspiration,** intra-alveolar pressure decreases below atmospheric pressure. It becomes **-1 mmHg** less than atmospheric pressure due to expansion of chest & lungs. So, air rushes in.
- During normal **expiration,** intra-alveolar pressure increases above atmospheric pressure to equal **+1 mmHg** due to elastic recoil of lung & chest. So, air forces out.
- At the end of inspiration or expiration, intra-alveolar pressure = 0 mmHg

[2] Intrapleural pressure

Definition:

It is the pressure between the two layers of the pleura i.e. between the visceral pleura and the parietal pleura.

- The intra-pleural space contains few centimeters of lymph for lubrication of movements. Normally, it does not contain air.

- During normal respiration, the intra-pleural pressure is **Negative.**

Values of intra-pleural pressure (IPP)

- At end of normal expiration → -4 mmHg
- At end of normal inspiration → -6 mmHg
- With deep inspiration → -12 mmHg because with deep inspiration there is maximal expansion of lungs → IPP becomes more negative.
- During forced inspiration against closed glottis (Muller's experiment) → IPP becomes -30 to -50 mmHg. → increase the venous & lymphatic suction
- During forced expiration against closed glottis (Valsalva's experiment) → IPP becomes + 50 mmHg → decrease the venous & lymphatic suction (fainting during straining)

- **IPP becomes positive in:**

- Valslava's experiment: forced expiration with glottis closed
- Pneumothorax

Significance of Intra-pleural pressure:

1) It prevents lung collapse and allows for lung expansion

2) It helps respiratory movement (pressure inside alveoli is positive while outside is negative)

3) It helps venous & lymphatic return from extra-thoracic vessels.

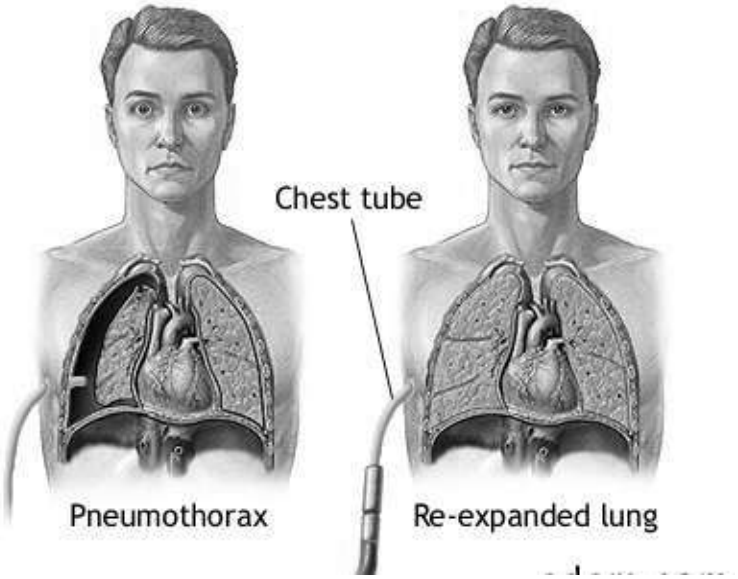
Pneumothorax

Definition: A collection of air in the pleural cavity leading to collapse of the lung .

Causes:

- Open pneumothorax: e.g. stab wound, pleural cavity is connected to atmosphere. Fatal, if bilateral.

- Closed pneumothorax: rupture of emphysematous bulla into pleural sac.



Control of respiration

Neural control

Voluntary control:

- Voluntary apnea

- Voluntary hyperventilation

- Nerve impulses pass from cerebral cortex → motor neurons of respiratory muscles.

Involuntary spontaneous control:

- Pontine and medullary respiratory centers

Medullary centers:

- Dorsal respiratory group (DRG) = Inspiratory center
- Ventral respiratory group (VRG) = Expiratory center
- Inspiratory centers and expiratory centers show Reciprocal innervation.

Pontine centers:

- Pneumotaxic center:
  - Present in upper pons
  - Inhibits both apneustic and inspiratory center → end of inspiration.

- Apneustic center:
  - Present in lower pons
  - Stimulates inspiratory center

Automatic Breathing

- Apneustic center sends impulses → stimulation of inspiratory center.

- Inspiratory center sends rhythmic continuous impulses through spinal cord to motor neurons of inspiratory muscles.

- Contraction of inspiratory Muscles → inspiration.

- Inspiration is terminated by:
  1. Lung Stretch reflex
     lung inflation → ++ of stretch receptors in alveolar wall → send inhibitory impulses to both apneustic and inspiratory centers along vagus nerve.
  2. Pneumotaxic center: is stimulated by apneustic center then sends inhibitory impulses to both apneustic and inspiratory centers.

- Expiration occurs passively after inspiration is terminated.

Cyanosis

- **Definition:** Bluish discoloration of the skin and mucous membrane due to increased deoxy-hemoglobin (reduced Hb) above 5 gm% in arterial blood.

- **Types:**
  1. Central
  2. Peripheral

Central Cyanosis:
- Means decreased O_2 saturation of Hb in arterial blood.
- Detected in buccal mucosa and lips.
- Seen in case of left ventricular failure and severe lung disease.

Peripheral Cyanosis:
- Means slowing of blood circulation of fingers and toes.
- Detected in cold, ischemia or arterial coagulopathy of the limbs..
- Seen in nail beds

Factors affect cyanosis:
- Racial skin pigmentation and Black race
- Jaundice
- Anemia

Hypoxia

- **Definition:** O_2 lack at the tissue level. May be due to decrease O2 supply or decreased O_2 utilization ability.

- **Types:**
  - **Hypoxic**
  - **Stagnant**
  - **Anemic**
  - **Histotoxic**

Hypoxic Hypoxia:
- Most common type seen clinically

- Causes:
  - Low oxygen tension in inspired air (high altitude, mines)
  - Severe lung diseases e.g. T.B, fibrosis…etc.

- Cyanosis is present

Stagnant Hypoxia:

- Inadequate blood flow through tissue

- Causes:
  - Low cardiac output: In heart failure and shock
  - Vascular obstruction of veins or arteries

- Cyanosis is present

Anemic Hypoxia:

- Deficiency of normal Hb.

- Causes:
  - Quantitative (decreased normal Hb): In all types of anemia
  - Qualitative (abnormal form of Hb) e.g. CO poisoning.
    CO (carbon monoxide) is toxic gas formed by incomplete consumption of carbon or gasoline. The affinity of Hb to CO is 210 time its affinity to O2 to form Carbomonoxy Hb.

- Cyanosis is not present.

- The patient is plethoric (red due to Carbomonoxy Hb)

Histotoxic Hypoxia:

- Inhibition of tissue oxidative process or cytochrome system.

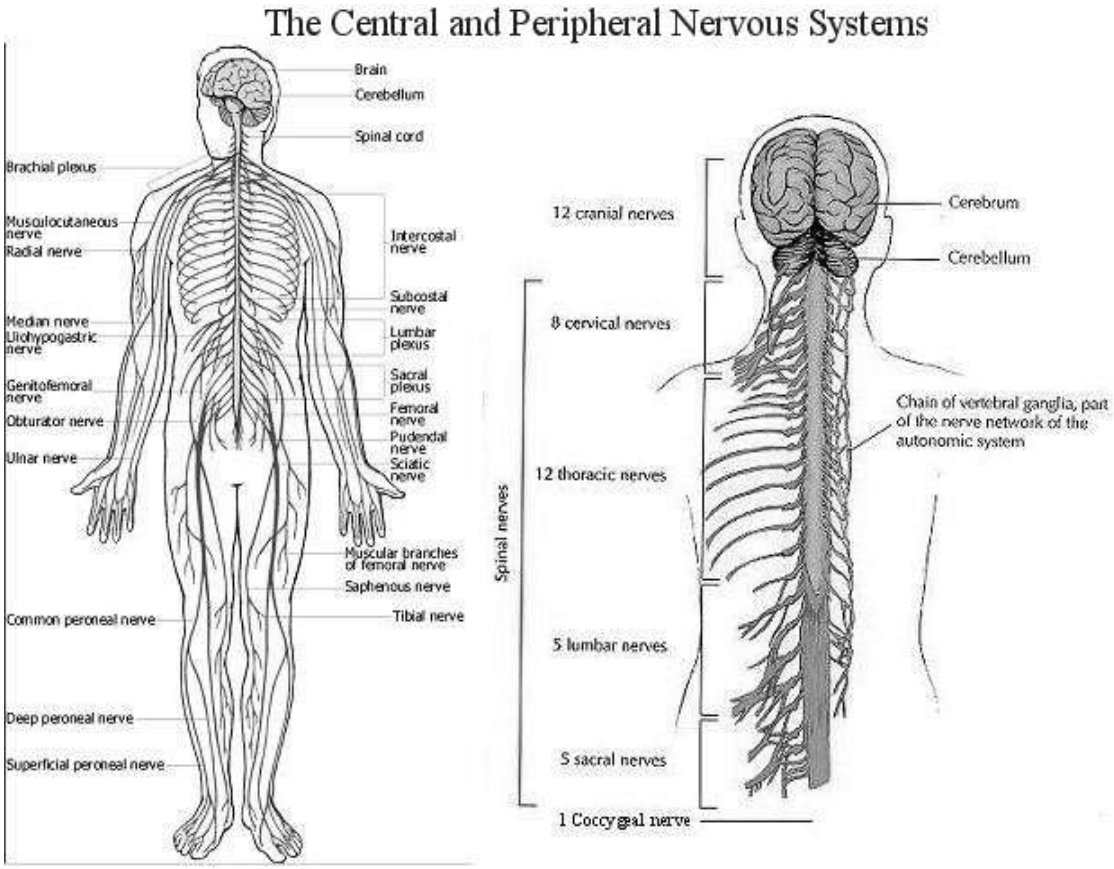
- Causes:
  - Cyanide poisoning
  - Cyanide inhibits the cytochrome oxidase enzyme which is needed to conduct O_2 to the tissues to be utilized.

$$\text{Reduced cytochrome} + O_2 \xrightarrow{\text{Cytochrome oxidase}} \text{Oxidized cytochrome}$$

- Cyanosis is not present.

Nervous system

- The nervous system coordinates the rapid activities of the body through fast transmission of impulses.
- The nervous system is divided into central and peripheral parts
- The central nervous system contains the brain and the spinal cord.
- The peripheral nervous system contains sensory nerves and motor nerves.



Reflex Arc:

The reflex arc is the basic functional unit of the nervous system. The reflex arc allows the body to react involuntarily and automatically to a variety of internal and external stimuli.

The reflex arc consists of:

1- Receptor: Specialized structure present at the end of sensory nerves that receives the stimulus and converts it into action potential.

2- Afferent neuron: It is the sensory neuron that transmits the sensory information from the receptor to the spinal cord.

3- Center: Present in brain or spinal cord and relays information from the sensory afferent neuron to the motor efferent neuron.

4- Efferent neuron: It is the motor neuron that transmits instructions from CNS to the effector organs.

5- Effector organ: Smooth, skeletal or cardiac muscles and glands.

So, the nervous system can be functionally divided into three main divisions:

I-Sensory division: - General somatic sensation

- Special sensation

II- Center: Brain and spinal cord

III- Motor division: - Motor Somatic (voluntary) to skeletal muscles

- **Motor autonomic** (involuntary) to smooth muscle, cardiac muscle or glands.

General somatic sensations

1. Mechano-receptive Sensation:

A- Tactile sensation:

1. Touch:

a) Crude touch.

b) Fine touch: which includes 4 types:

1. Tactile localization: localization of a point touched without looking.
2. Tactile discrimination: differentiation between two points applied to the skin without looking.
3. Stereognosis: ability of the person to know an object from its shape, form and texture provided he is closing his eyes.
4. Texture: ability of the person to know texture of different materials with eyes closed.

2. **Pressure**
3. **Vibration:** It is the ability to feel the vibration of a tuning fork put on any bony prominence of the body.
4. **Tickling and itching**: Ability to feel light moving things on the skin e.g. insects.

B- Position senses (Proprioceptive senses)

[2] Thermal Sensation:

Types of thermal receptors:

a- Cold receptors.

b- Warm receptors.

c- Cold pain receptors and heat pain receptors.

[3] Pain sensation

- Pain is unpleasant sensation. It occurs when there is tissue damage. Pain sensation is a protective mechanism for the body.

Causes of pain:

1. Mechanical, thermal or chemical injury of the skin.
2. Ischemia: decreased blood supply to the tissues.
3. Inflammation of peritoneal covering of viscera.
4. Irritation: chemical irritation by Hcl in peptic ulcer.
5. Over-distension of a hollow viscous (e.g. urinary bladder)

6. Spasm of a hollow viscous e.g. gut, gall bladder.

Headache:

- Type of referred pain to the surface of the head from deep structures:

1- Headache of intra-cranial origin:

Causes

- Meningitis: due to inflammation of meninges.
- Meningeal trauma: due to meningeal irritation.
- Brain tumors: due to irritation of meninges.
- Migraine headache: due to marked dilatation of cerebral arteries.
- Low cerebrospinal fluid: removal of cerebrospinal fluid leads to sinking of the brain due to its weight and causes meningeal traction.
- Constipation headache: due to irritation of meninges by toxins absorbed from the rectum.

2- Headache of extra-cranial origin:

Causes

- Sinusitis, Allergic rhinitis.
- Errors of eye refraction, Glucoma.
- Dental abcess,Tooth ache.
- Otitis media.
- Spasm and traction of neck muscles.

Special sensations

- **Vision: by the eye**
- **Hearing: by the ear**
- **Taste: by the tongue**
- **Smell: by the nose**

The eye:

The iris of eye:

Is the pigmented perforated disc in the eye. The hole is the **pupil**. It contains pupilloconstrictor & pupillodilator muscles.

The pupil:

- Is the central opening of the iris.
- Pupillo-constriction due to contraction of pupilloconstrictor

muscle is called **meiosis.**

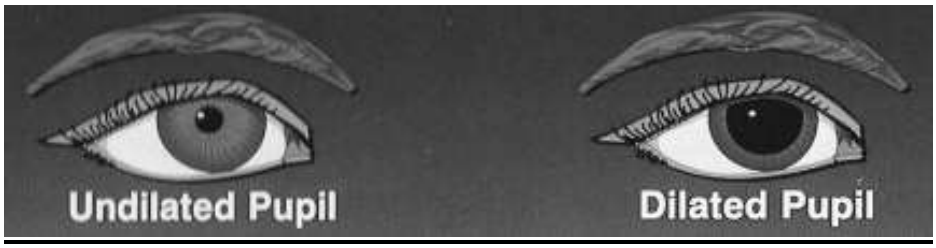
- Pupillo-dilation due to contraction of pupillodilator muscle is called **mydriasis.**
- The pupil which can be constricted and dilated is called reactive Pupil.

Causes of meiosis:

- Light exposure
- Near vision e.g during reading
- Parasympathetic stimulation
- Drugs

Causes of mydriasis:

- Dark exposure
- Sympathetic stimulation
- Drugs



Light reflex:

Sudden exposure to light in one eye leads to meiosis in both eyes.

- Stimulus: light exposure in one eye
- Afferent: optic nerve (Cranial nerve II)
- Center: Midbrain of brain stem.
- Efferent: Occulomotor nerve (Cranial nerve III)
- Effect: meiosis in both eyes

Refraction errors:

- **Myopia (nearsightedness):** the eye sees better near than at a distance. This is because light is bent too much and focuses in front of the retina.

- **Hyperopia (farsightedness):** The eye sees better at distance than at near**.** This is because light is not bent enough and focuses behind the retina.
- **Astigmatism (uneven cornea):** An irregular bending of light rays that results in blurring of vision at all distances.

- **Presbyopia (aging eye).** This normal condition occurs in aging. It is the loss of the ability to focus on near objects.

The ear:

- The ear has three parts: External, Middle and Inner ear.
- The External and Middle ear are for conduction of sounds.
- The Inner ear is for perception of sounds and its transformation into action potentials for hearing. It is also concerned with equilibrium.

Deafness

- It is inability to hear sounds. The types are:

(A) Conductive deafness: It is due to interference with conduction of sound to internal ear e.g. obstruction of external ear by wax or foreign body, middle ear disease e.g. perforated ear drum.

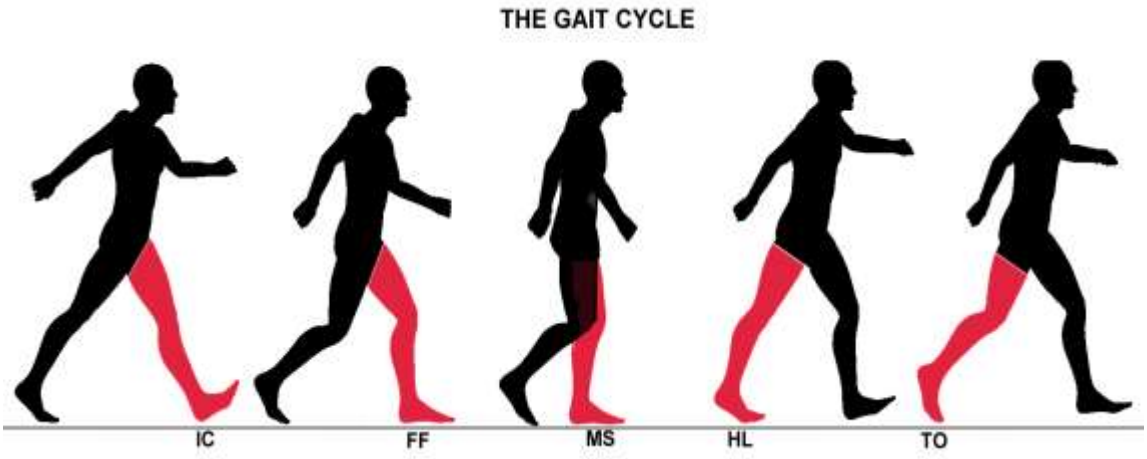
(B) Nerve deafness: it is due to lesion of choclea or its auditory nervous pathway e.g. by toxins or inflammation.

- It is tested by tuning fork.

The gait

Normal **gait** is rhythmic, alternating propulsive and retropulsive motions of lower limbs.

It requires that many systems, including muscle strength, sensation and coordination, function in an integrated fashion.



Abnormal gait

Causes:

Pain, Joint disorder, muscle weakness or paralysis, neurological disorders (UMNL or LMNL), leg length discrepancy.

Examples:

1. Limping gait: due to pain
2. Circumductory gait: due to spastic hemiplegia
3. Scissoring gait : due to spastic paraplegia
4. Waddling (duck) gait: due to flaccid paralysis of
5. Stampic gait (high steppage gait) due to sensory ataxia in case of loss of propioceptive sensation.
6. Drunken gait: due to motor ataxia in cerebellar dysfunction.
7. Shuffling gait: as in parkinsonism due to leision of basal Ganglia.

Digestive system

- Is composed of :
  - The alimentary tract: mouth, pharynx, eosophagus, stomach, small intestine, large intestine, rectum and anal canal.
  - The different glands like the salivary glands, the liver and pancreas.

- The alimentary tract provides the body with water, electrolytes and nutrients.

- This is achieved by: movement of food in gastro-intestinal tract (GIT), secretion of digestive juices, absorption of digestive products, circulation of food through GIT & control of these functions by nerves & hormones.

- Gastrointestinal functions are under control of:

1) Autonomic nerves (sympathetic & parasympathetic)
2) Gastrointestinal hormones

Salivary Glands

1- Parotid gland
2-Sublingual gland
3-Submandibular gland

- It is under nervous control only (through autonomic nervous system).

Composition of saliva;

(1) Volume: 1500 ml/day
(2) pH: 7.1 - 7.4 slightly alkaline
(3) Contents:

► Digestive enzymes: Amylase and lingual lipase
► Electrolytes: large quantities of K+ and HCO3- and low Na+ & Cl-.
► Immunoglobulin A (IgA): to defense against bacteria &viruses.
► Lysozyme: which attack bacterial wall.

Functions of saliva:

1. **Articulation:** saliva moistens mouth & aids speech.
2. **Buffer:** saliva contains bicarbonate & mucin which maintain oral pH at 7.1. At this pH, the saliva is saturated with calcium. So teeth do not lose calcium to oral fluid. Loss of calcium from teeth leads to dental caries.
3. **Cleaning & antibacterial action:** saliva contains lysozyme.
4. **Cooling**: of hot food
5. **Digestion:** saliva contains salivary amylase which digests starches into disaccharides.
6. **Swallowing:** saliva lubricates food because of its mucin.
7. **Excretion:** of mercury & lead.
8. **H_2O regulation:** dryness of saliva leads to thirst.
9. **Heat regulation** : in panting animals with no sweat glands

Mastication (chewing)

- It is rhythmic opening & closure of mouth.
- Importance:
  1- It breaks large food particles into smaller ones.
  2- Stimulates taste buds & smell receptors.
  3- Stimulates salivary secretion which helps swallowing.

Swallowing (Deglutition)

- It is initiated voluntary & completed involuntary.
- Center: Medulla
- Stages: Buccal, pharyngeal and esophageal.

(1) Buccal (Oral) phase: it is voluntary

(2) Pharyngeal phase:

- It is involuntary (reflex). It is passage of food through pharynx into esophagus.

- The bolus is prevented from passing to:
  a) Nose which is closed by elevation of soft palate.
  b) Mouth which is closed by elevation of tongue.
  c) Larynx which is closed by:
    - Elevation of larynx to be covered by epiglottis.
    - Closure of glottis (approximation of vocal cords), destruction of vocal cord or its muscles → strangulation.

- Inhibition of respiration (swallowing apnea as swallowing center inhibits the respiratory center in medulla).

- The pharyngeal stage occurs in 1 to 2 seconds.

(3) Esophageal stage:

- It is involuntary. It is passage of food from esophagus to stomach.

- The following occurs:

A- The Upper Esophaqeal Sphincter (UES): It relaxes during the passage of food, and then it contracts.

B- Traveling along the esophagus:

- Fluid travels by gravity.
- Bolus of food travels by peristalsis.

C- Lower esophageal sphincter (LES) (gastro-oesophageal sphincter):

- It is a physiologic sphincter
- It is tonically constricted (in contrast to mid & upper part of esophagus which are normally relaxed)
- It prevents the regurgitation of gastric HCl to esophagus.
- If the pressure in the LES is decreased, gastric HCl will regurgitate to the esophagus leading to heart burn.

Stomach

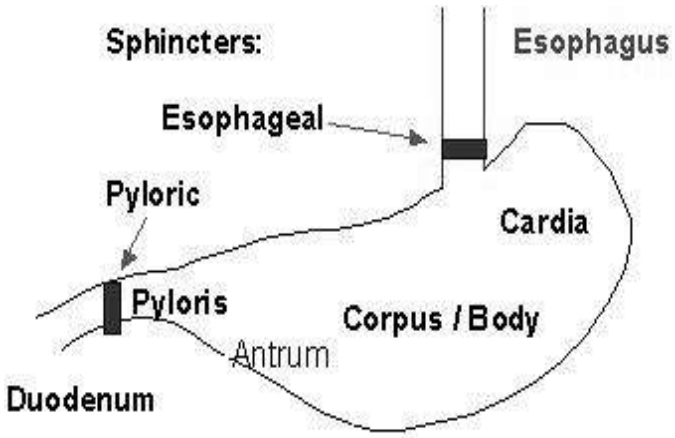
- Food is stored in stomach, mixed with acid, mucus, pepsin, released into duodenum.

- The gastric mucosa contains many deep glands.

- In the pyloric & cardiac regions, the glands secrete mucus.

- In the body & fundus, the glands contain:
  - Parietal cells (oxyntic): secrete Hcl and intrinsic factor.
  - Chief cells (peptic = zymogen): secrete pepsinogen.
  - Cells in the neck of the glands: secrete mucus

$$\text{Proteins} \xrightarrow{\text{Pepsin}} \text{Peptides}$$



Gastric secretion

- **Volume:** 2.5 - 3 liters/day
- **pH:** highly acidic (pH 2-3)
- **Constituents:**

- Water
- Ions: H +, Cl -, Na + & K +
- Enzymes: pepsinogen, gelatinase & lipase.
- Mucus
- Intrinsic factor for absorption of vitamin B12

Functions of HCl:

1) Activation of pepsinogen to pepsin.
2) Aids protein digestion.
3) Dissolves food particles changing them into chyme
4) Cause precipitation of milk in stomach, so milk is exposed for long time to pepsin.
5) Kills the bacteria.
6) Helps in absorption of iron & calcium.

Factors affecting Stimulation of acid secretion:

(1) Nervous: Vagus & intrinsic plexus:
50% of nerve signals to stomach are through vagus, the other 50% are through local reflexes (enteric nervous system).

(2) Hormones: Gastrin and Histamine increase acid secretion.

Vomiting

- **Definition:** It is reflex emptying of gastric content through the mouth.
- **Center:** Medulla
- **Mechanism:**

Before vomiting: Nausea, salivation, sweating & tachycardia.

During vomiting:

A- Stomach: - It is completely passive
- Relaxation of the wall of the stomach.
- Relaxation of the lower esophageal sphincter.
- Contraction of pyloric area.

B- Strong contraction of diaphragm & abdominal muscles leading to increase intra-abdominal pressure which squeezes the content out of the stomach.

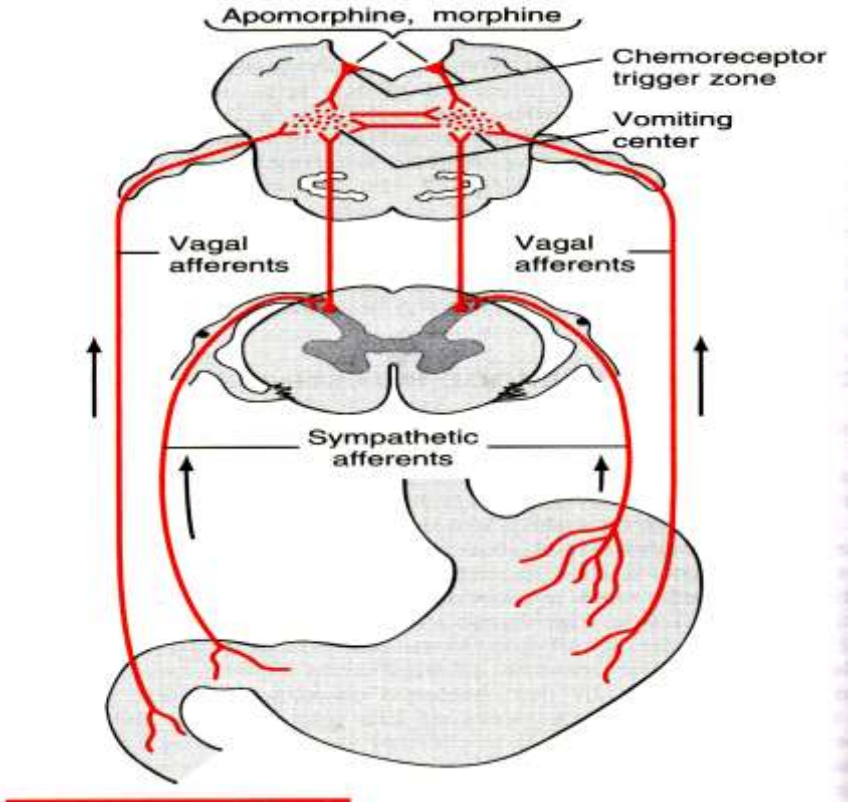
C- Protective reflexes to protect air passages:
- Nose: elevation of soft palate to close the nasal cavity.
- Closure of glottis and apnea.

Causes of vomiting or types of vomiting:

(1) Reflex causes: afferent in sympathetic & vagus from mucosa of upper GIT.
- **a-** Mechanical stimulation of the posterior part of the tongue.
- **b-** lrritation of gastric mucosa.
- **c-** lntestinal obstruction.
- **d-** Visceral pain e.g. renal colic and appendicitis.

(2) Central causes: stimulate chemoreceptor trigger zone in medulla.
- **a-** Drugs e.g. apomorphine.
- **b-** Hypoxia , acidosis and uremia.
- **c-** Motion sickness : due to afferents from vestibular nuclei.
- **d-** Conditioned reflexes: e.g. Nauseating smells and sickening sights.

Effects of vomiting:
1. Dehydration leading to hypotension & tachycardia.
2. Alkalosis: due to loss of HCl leading to tetany.
3. Hypokalemia due to potassium loss.



LIVER

Functions of the liver:

The function of the liver can be classified into:

1) <u>Vascular functions for storage and filtration of blood:</u>

i- The liver can store 200-400 ml. of blood. In hemorrhages large amounts of blood in the liver sinusoids drain into circulation to replace the lost blood.

ii- The liver sinusoids are lined with many Kupffer cells, which are highly phagocytic, so that they can remove about 90% of bacteria in the portal venous blood (in particular the colon bacilli) before they can pass through the liver sinusoids.

2) Metabolic functions:

***a-* Carbohydrate metabolism:**

The liver functions as a sort of "glucostat" maintaining a constant circulating glucose level under the effect numerous hormones:

i- Formation and storage of glycogen (glycogenesis).

ii- Breakdown of glycogen into glucose (glycogenolysis).

iii- Formation of glucose from non-carbohydrate sources (gluconeogenesis).

iv- Conversion of galactose and fructose to glucose.

***b-* Fat metabolism:**

Oxidation of fatty acids to supply energy for other bodily functions.

***c-* Protein metabolism:**

i- Deamination of amino acids before they can be used for energy or before they can be transformed into carbohydrates or fats.

ii- Formation of urea for removing of the ammonia.

iii- Most plasma proteins are formed by the liver cells (about 90%), with the exception of part of the gamma globulins, which are formed in the lymphatic tissues of the body. Also, the liver forms most of the coagulation factors.

iv- Synthesis of all the non - essential amino acids.

***d-* Storage of vitamins: Such as vitamin A, D and B_{12}.**

***e-* Storage of iron**

***f-* Detoxification or excretion of drugs, hormones and other substances into bile.**

3) Secretory and excretory functions:

formation of bile for fat digestion.

Female Reproductive System

It includes:

- **Primary sex organs:** 2 ovaries that secrete hormones & Oogenesis occurs within them.
- **Secondary sex organs:** 2 fallopian tubes – uterus - vagina - bartholin gland-external genitalia - 2 mammary glands.

Actions of Estrogens

- **Intrauterine life:**
  ► Development of uterus and vagina
  ► Masculine the male brain for male sex behavior.

- **At puberty: effects on:**
  1- Primary sex organs
  2- Secondary sex organs
  3- Secondary sex characters
  4- Metabolism

- **Primary sex organs (ovaries)**
  Facilitates growth of ovarian follicles
  Stimulate LH surge → Ovulation

- **Secondary sex organs**

1) Uterus: Endometrium and myometrium

- Endometrium:
  - Regeneration and proliferation of the cells in follicular phase.
  - Increase gene expression of progesterone receptors.

- Myometrium: Increases
  - The uterine blood flow.
  - The amount actin and myosin.
  - Excitability and spontaneous contractility.
  - Number and sensitivity of oxytocin receptors.

- Cervix:
  Secretion of thin alkaline mucus (facilitates sperm transport)

- Vagina:
  - Increased the layers of mucosal lining.
  - Increased glycogen deposition and lactic acid production to kill bacteria.

- Fallopian tubes:
  - Increase motility and number of cilia to propel fertilized ovum towards the uterus.

- External genatalia: Growth

- Breasts:
  - Enlargement at puberty
  - Increase fat deposition
  - Increase blood flow
  - Growth of the ducts and nipple
  - Pigmentation of the areola

Actions of Progesterone

(1) On primary sex organs (ovaries)

- Progesterone in minute amounts in the preovulatory stage shares in LH surge.
- But Large oral doses of progesterone can inhibit LH secretion and ovulation.

(2) Secondary sex organ

- Uterus:
  1- Stimulates the secretory changes of the endometrium to help implantation of the fertilized ova.
  2- Help formation of placenta
  3- Maintain pregnancy

- Cervix: Stimulate mucus secretion (thick, Viscid and cellular)

- Vagina:
  Stimulates thick vaginal secretions.

- Fallopian tubes:
  Stimulates secretion of mucous necessary for the nutrition of the fertilized ovum

- Breasts:
  - Stimulates the development of lobules and ducts of the glands.
  - Supports the secretory function of breast during lactation.

(3) Thermogenic action: direct action on heat regulating center.

(4) Respiration: increases respiration.

(5) Appetite: increases appetite

(6) Maternal behavior

(7) Electrolyte: increases Na^+ and H_2O excretion.

Fertilization: Process of fusion of the sperm with the ovum to produce zygote.

Menopause:

- Definition: Stoppage of both ovarian and menstrual cycles with lack of female sex hormones.
- Age: 45 to 50 years old
- By time and at 45 years old, the number of ovarian follicles decreased to few follicles which secrete little amount of estrogen
- By time no estrogen production.
- Manifestations:
  1- Secondary Amenorrhea.

2- Osteoporosis
3- Gradual loss of secondary sex characters.
4- Psychic effect: anxiety, irritability, depression, dyspnea.
5- Hot flushes (unknown cause).

Menstrual Cycle Physiology

- In the normal menstrual cycle, there is an orderly cyclic hormone production and parallel proliferation of the uterine lining in preparation for implantation of the embryo.
- Disorders of the menstrual cycle and, likewise, disorders of menstrual physiology may lead to various pathologic states, including infertility, recurrent miscarriage, and malignancy.
- Disorder of menstruation is one of the most frequent reasons women seek medical care.

Normal Menstrual Cycle

- The normal human menstrual cycle can be divided into two segments: the ovarian cycle and the uterine cycle, based on the organ under examination.

Phases of ovarian cycle

Follicular phase

- Hormonal feedback promotes the orderly development of a single dominant follicle, which should be mature at mid-cycle and prepared for ovulation.
- The average length of the human follicular phase ranges from 10 to 14 days, and variability in this length is responsible for most variations in total cycle length.

Luteal phase

- The time from ovulation to the onset of menses, with an average length of 14 days.
- A normal menstrual cycle lasts from 21 to 35 days, with 2 to 6 days of blood flow and an average blood loss of 20 to 60 ml.
- The extremes of reproductive life (after menarche and peri-menopause) are characterized by a higher percentage of anovulatory or irregularly timed cycles.

Phases of uterine cycle:

Proliferative (Estrogenic) Phase:

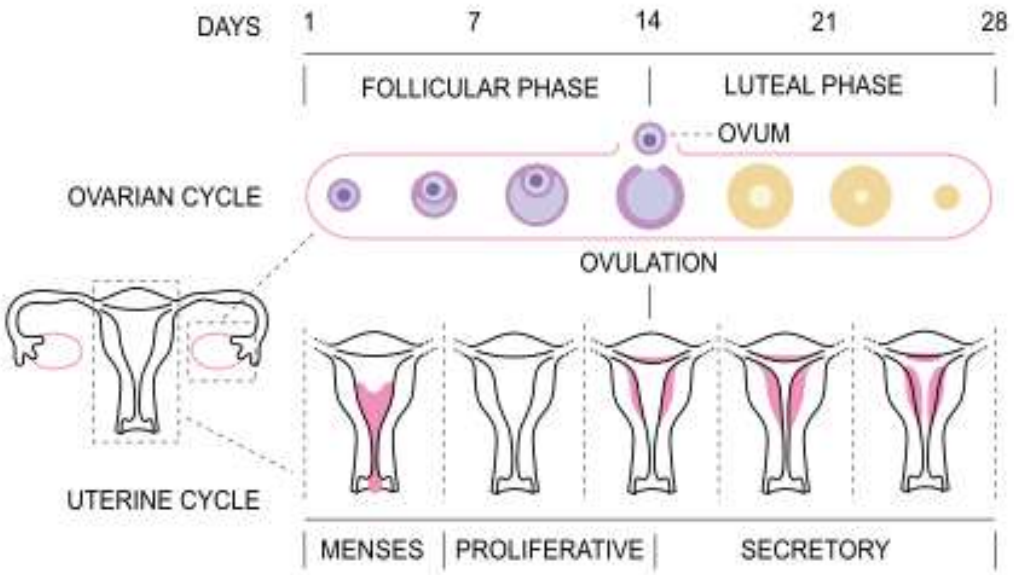
- The first day of vaginal bleeding is called day 1 of the menstrual cycle.
- Duration : from 5^{th} day of cycle to 14^{th} day (ovulation)
- Control : Estrogen secreted from growing ovarian follicle (during follicular phase of ovarian cycle)
- Changes: - Progressive increase in the number of endometrium cells
  - Straight, narrow, and short endometrial glands with minimal secretions.
  - At the beginning of the proliferative phase, the endometrium is relatively thin (1 to 2 mm) then reaches 3-4 mm by time of ovulation.

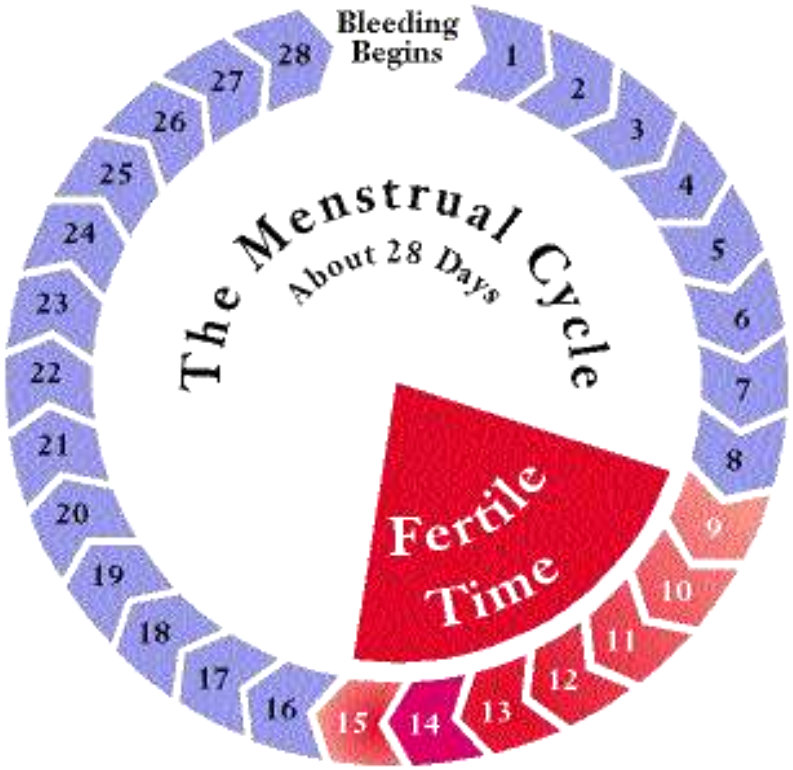
Secretory Phase:

- In the typical 28-day cycle, ovulation occurs on cycle day 14. Within 48 to 72 hours following ovulation, the onset of progesterone secretion produces a shift in histologic appearance of the endometrium to the secretory phase.
- Duration : 14^{th} day till onset of menstruation
- Control : Progesterone mainly and estrogen from corpus luteam
- Changes: - Endometrial glands become tortuous and secretory
  - spiral arteries become more tortuous
  - The cells are edematous with lipid and glycogen deposition.
  - Endometrium is 5-6 mm thick .

Degenerative phase (Menstruation):

- Duration: 3- 7 days.
- Control & changes: degeneration of corpus luteum leads to --> drop in estrogen and progesterone level in blood leading to :
  - Constriction of spiral arteries: leading to ischemic necrosis of superficial functional layer of endometrium.
  - Dilatation of spiral arteries follows leading to —> gush of blood which removes endometrium + unfertilized ovum.


DAYS
1
7
14
21
28
FOLLICULAR PHASE
LUTEAL PHASE
OVUM
OVARIAN CYCLE
OVULATION
UTERINE CYCLE
MENSES
PROLIFERATIVE
SECRETORY


Bleeding Begins
The Menstrual Cycle
About 28 Days
Fertile Time
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Male reproductive system

Consists of:

(1) Primary sex organ: 2 testes, for sperm production and testosterone secretion

(2) Secondary sex organs (ducts: i.e. vas deferens & epididymis and secretory sex glands as seminal vesicles-prostate-bulbourethral glands.

(3) External organs: Penis

Functions of testosterone:

(A) During intrauterine life:

1) Growth & development sex organs.

2) Descending of testis into scrotum at 8th month.

(B) At Puberty & During adult life:

I - Masculinizing effects:

(1) On primary sex organs: testosterone is essential for sperm production and maturation (spermatogenesis).

(2) On secondary sex organs:

Testosterone is essential for growth, maturation, maintenance of seminal vesicle, prostate, bulbourethral gland and external genitalia (penis, scrotum).

(3) On secondary sex characters:

- Hairs: increase body hair (face, chest, axilla). Decrease scalp hair (baldness)-hairline is indented in the lateral frontal region. Moustache & beard & pubic hairs
- Skin: thickened, excessive thick secretion of sebaceous glands (acne)
- Voice: deep-low pitch voice. larynx and vocal cords are enlarged.
- Body Conformation: wide shoulder-narrow pelvis.
- Behavior: increase libido (sexual desire)-aggressive.

II- General metabolic effects:

- Protein anabolic effect: sex organs, muscle, bones
  - Increase muscle bulk

- Increase bone matrix & deposition of calcium (treatment of osteoporosis)
- Growth spurt at time of puberty, then closure of epiphysis.
- Increase basal metabolic rate & RBCs count

The semen

1) **pH:** alkaline (7.4) - white color
2) **Rich in** fibrin, fibrinolysin, hyaloronidase, fructose, buffer
3) **Volume :** 2 - 4 ml/ejaculate
4) **Number:** 80 -100 million sperm/ml
    - Oligospermia: If less than 50 million sperm/ml (subfertile) or less than 20 million sperm/ml (infertile)
    - Azospermia: Zero sperm.
5) **Viscosity:** Viscid but high viscosity limits motility
6) **Motility:** 60 % of sperms are motile
7) **Morphology:** less than 25% are abnormal (2 heads-forked tail)
8) **Fructose.**
9) **Specific gravity:** 1028
10) **Semen contains:**
    - Sperms
    - Buffers: bicarbonate – phosphate - hyaluronidase.
    - Seminal vesicle secretion (60%): Fructose.
    - Prostatic secretion (30 %): Cholesterol - phospholipid

There is low fertility if:

- Semen: low volume - low fructose - high viscosity.
- Sperm: low number - low motility - high abnormal forms.

Body temperature

Shell & core temperature:

• Rectal temperature (core temp) → 36.2- 37.6° C average 37° C.
• Axillary & oral temperature → 0.5° C less
• Skin temperature
  - head chest abdomen → 34° C
  - Extremities → 28° C

The thermoregulatory system

Thermoreceptors → center → effector organ system

Thermoreceptors

Peripheral → in the skin
Central → in the hypothalamus to measure core temp

Thermoregulatory center

- In hypothalamus - set point 37
- Temperature below 37 → stimulate posterior hypothalamus → activation of anti-drop mechanism → heat gain
- Temperature above 37 → stimulate anterior hypothalamus → activation of anti-rise mechanism → heat loss

Effector organ system

- Autonomic impulses → to blood vessels & sweet glands
- Somatic impulses → muscle tone & shivering
- Neuro-endocrine → secretion of adrenaline, T3 &T4, CRH & ADH
- Limbic lobe → stimulation of thirst & appetite sensations.

Regulation of body temp:

A constant body temp means heat gain equals heat loss

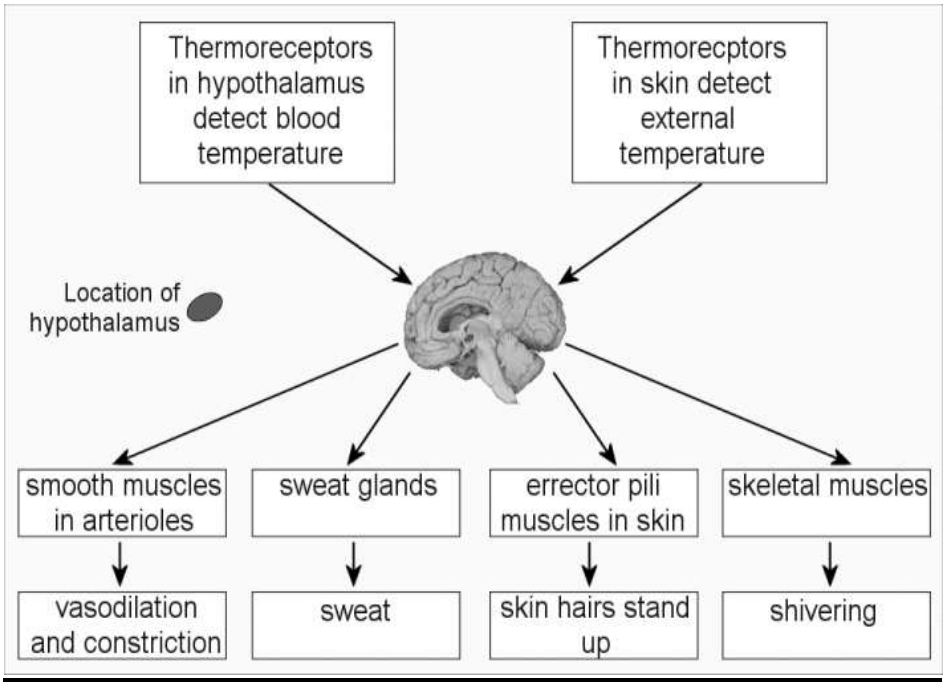
Ways of heat gain

- Increased muscle activity → muscle tone, shivering and voluntary muscle activity
- Hormonal → thyroid hormones & adrenaline

Ways of heat loss

- Non-evaporative heat loss → radiation, convection, conduction
- Evaporative heat loss

  1 cc of water in sweet evaporated → loss of 0.6 K cal.



Reaction of the body during exposure to cold

- **Increased heat gain:**
  - Increase muscular activity (shivering).
  - Increased adrenalin & T4 secretion.
  - Behavioral responses → increased food intake & warm drinks.
  - Piloerection of hairs.

- **Decreased heat loss:**
  - VC (vaso constriction) of skin vessels
  - Behavioral responses → heavy clothes & curling up.

Reaction of the body during exposure to heat

- **Decreased heat gain**
  - Decreased movement and muscle activity
  - Decreased food intake
  - Pilorelaxation of hairs

- **Increased heat loss**
  - VD (vasodilatation) of skin vessels
  - Increased sweat secretion
  - Light clothes & Stretching out of the body

Hot	Cold
Vasodilation Arterioles dilate (enlarge) so more blood enters skin capillaries and heat is lost.	**Vasoconstriction** Arterioles get smaller to reduce blood going to skin: keeping core warm.
Sweating Sudorific glands secrete sweat which removes heat when water changes state.	**Shivering** Rapid contraction and relaxing of skeletal muscles. Heat produced by respiration.
Pilorelaxation This means the hairs flatten.	**Piloerection** Hairs on skin stand up.
Stretching Out By opening up, the body was a larger surface area.	**Curling Up** Making yourself smaller so smaller surface area.

The end