SMART VISION INSTITUTE

نبراس Nebras

Physiology

Module Foundation

2029

في البداية نتمنى أن نكون قدمنا لكم ما يفيدكم و تتمنوه و نسألكم الدعاء لكل من كتب و أعاد صياغة هذا المحتوى و دققه ..

بشكل مباشر أو غير مباشر ...

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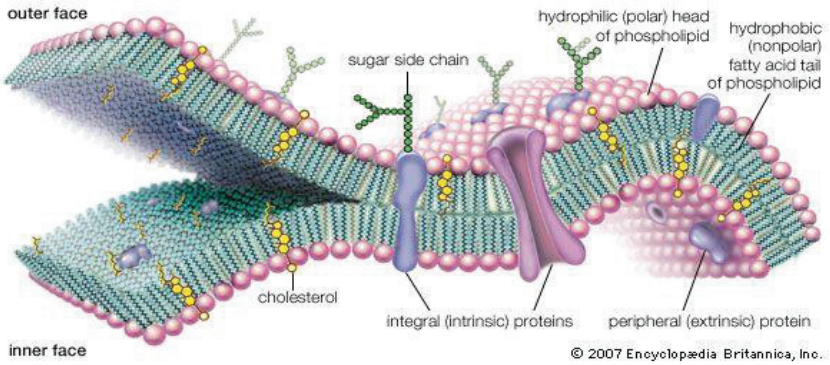
The Plasma Membrane Transport



Molecules That Can and Can not Diffuse Through the Membrane

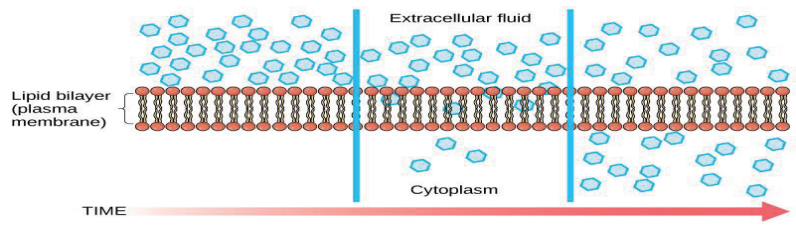
Category	Molecules
Can Diffuse	▪ Non-polar lipid-soluble molecules (e.g., oxygen, carbon dioxide) through the lipid bilayer. ▪ Small water-soluble molecules (e.g., electrolytes) through channels. ▪ Large molecules (e.g., glucose, amino acids) by facilitated diffusion.
Can not Diffuse	▪ Large molecules with high molecular weights (e.g., proteins).

Types of Transport

Type of Transport	Active Transport	Passive Transport
Direction of Movement	Against concentration gradient (uphill)	According to concentration gradient (downhill)
Energy Requirement	Requires energy (ATP)	No energy required

1. Passive Transport:

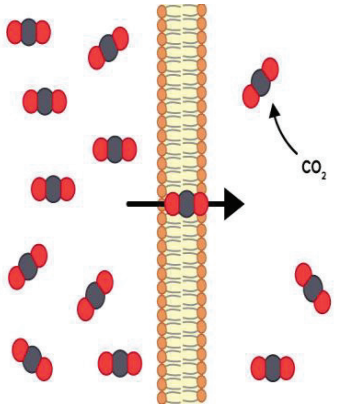
- **Definition:** It is the transport of molecules through the cell membrane from areas of high concentration to areas of low concentration,



Types of Passive Transport :

Type	Description
Simple Diffusion	▪ Transport of substances through the lipid bilayer or through channel proteins of the cell membrane.
Facilitated Diffusion	▪ Transport in combination with a carrier protein, utilizing the kinetic energy of molecules.

a. Simple diffusion:



- **Definition:**

It is the transport of substances either through:

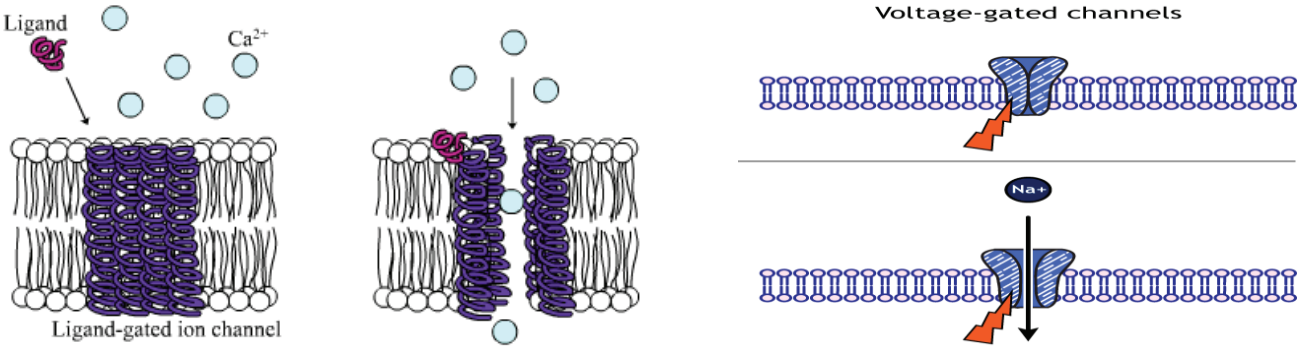
- The lipid bilayer or
- Through the channel proteins of the cell membrane.

- **Types :**

	Description	Example
Through Lipid Bilayer	Non-polar and lipid-soluble molecules.	▪ Oxygen diffuses from the blood into cells. ▪ Carbon dioxide diffuses from cells into the blood.
Through Protein Channels	Diffusion of small water-soluble molecules. (Channels are highly selective).	▪ Sodium channels selectively transport sodium ▪ Potassium channels selectively transport potassium

Types of the channel according to presence or absence of a gate:

Leak channels	Continuously opened.		
Gated channels	Controlled by gates.		
	1. Voltage-Gated Ion Channels	Open or close according to changes in membrane voltage.	Channels involved in nerve impulse transmission.
	2. Chemical (Ligand) Gated Ion Channels	Open or close by binding to a ligand (chemical substance).	Acetylcholine sodium gated channel at the neuromuscular junction.



- **Factors affecting the rate of simple diffusion (lipid bilayer or protein channel):**

1- Surface area of the membrane:

The greater the surface area of the membrane the higher the rate of diffusion.

2- Concentration gradient:

Increase in concentration difference of the substance on both sides of the membrane increases the rate of diffusion from high to low concentration.

3- Electrical gradient:

Ions passed from positively charged area to negatively charged one

4- Pressure gradient:

Molecules diffuse from areas of high pressure to areas of low pressure

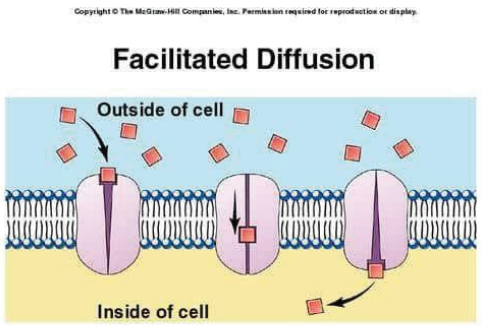
5- Permeability of the membrane:

The rate of diffusion increases by increasing the permeability of the membrane

Membrane Permeability:

- **Definition:** It is the rate of transport through a unit area of the membrane for a given concentration difference.
- **Factors affecting the permeability of the membrane:**
  1. The number of channels.
  2. The temperature: Increase in temperature → increase in motion of ions → increase the permeability.
  3. The resistance of the channel.
  4. The molecular weight (M.W.) of the diffusing substance (inverse relation with permeability)
  5. The thickness of the membrane: The greater the thickness of the membrane the lesser will be the permeability.

b. Facilitated (carrier-mediated) diffusion:



- **Definition:** transported substance uses a specific carrier protein.
- **Mechanism:**
  - The substance combines with a carrier protein, forming a complex.
  - The complex passes through the membrane.
  - The substance splits from the carrier on the other side of the membrane.
- **Type of Particles:**

  Large-sized polar lipid insoluble particles : Sugars and amino acids.
- **Factors affecting facilitated diffusion:**

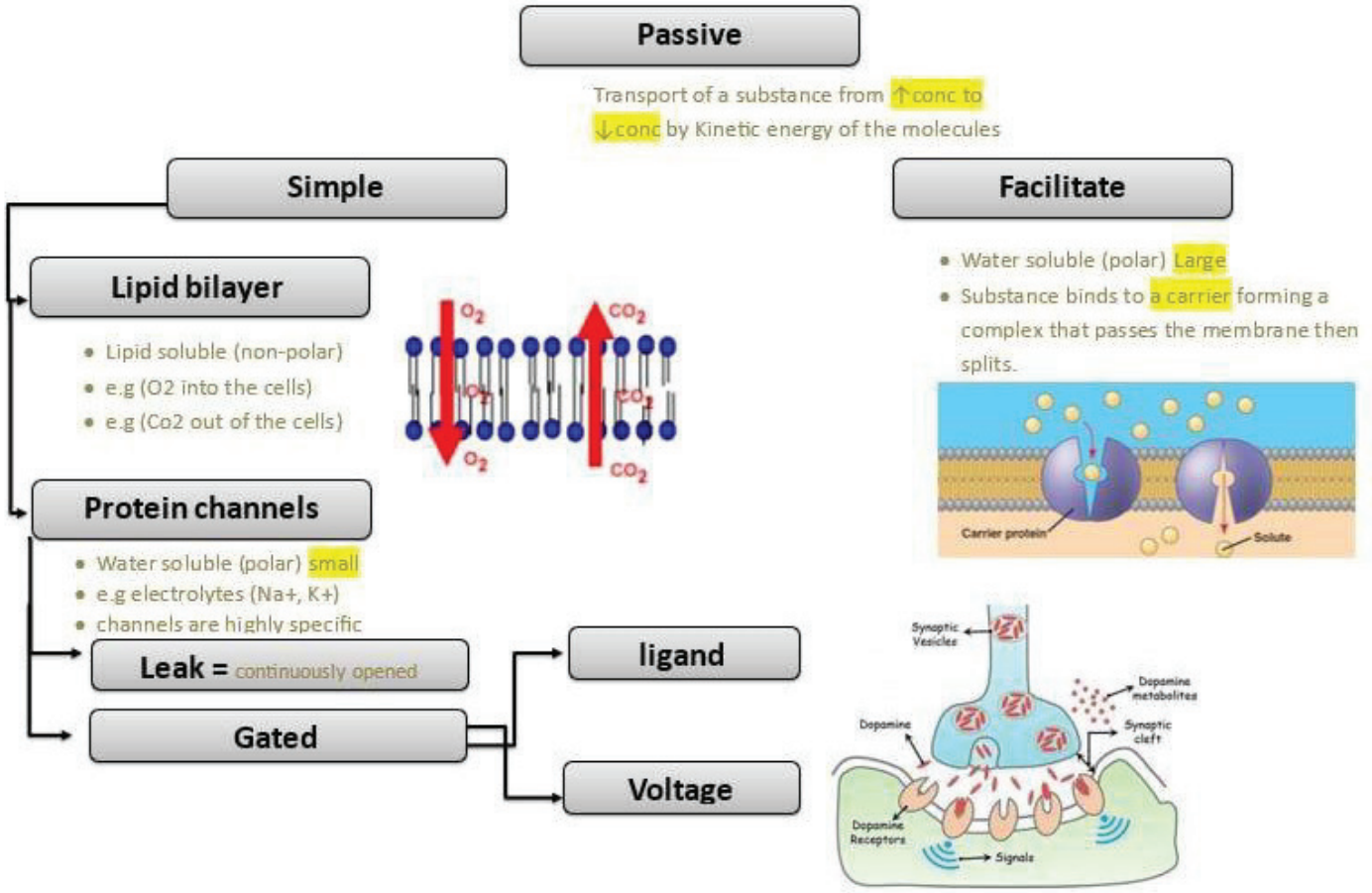
  1- The availability of the carrier.

  2- High concentration gradient of the substance through the membranes.

  3- Rapid combination and splitting of the carrier with the transported substance.

  4- Saturation of the carrier.

N.B: As glucose is normally in higher concentrations in the blood than in the cells, it can be transported from the blood into the cells in association with a specific carrier.



2. Active Transport

- **Definition:**
  - Active transport is the movement of substances across the membrane against concentration gradients (uphill).
  - It requires an additional source of energy derived from the cell.
- **Types of Active transport:**
  A. Primary active transport.
  B. Secondary active transport.

Type	Definition	Energy Source
Primary	Requires energy derived directly from the breakdown of adenosine triphosphate (ATP) or creatine phosphate.	ATP or creatine phosphate
Secondary	Uses energy derived indirectly from the concentration gradient of another substance.	Concentration gradient of another substance

A. Primary active transport:

- **Definition:** It requires energy derived directly from breakdown of adenosine triphosphate (ATP) or creatine phosphate.
- The most important example of a 1ry active transport is the sodium-potassium pump.

Sodium - potassium (Na-K) pump:

- **Definition:** It is a transport process that pumps sodium ions outward of the cell and at the same time pumps potassium ions from the outside to the inside of the cell against their concentration gradient.

- **Pump Function:**

The concentration of K inside the cell is higher than that outside, and the reverse is true of Na+

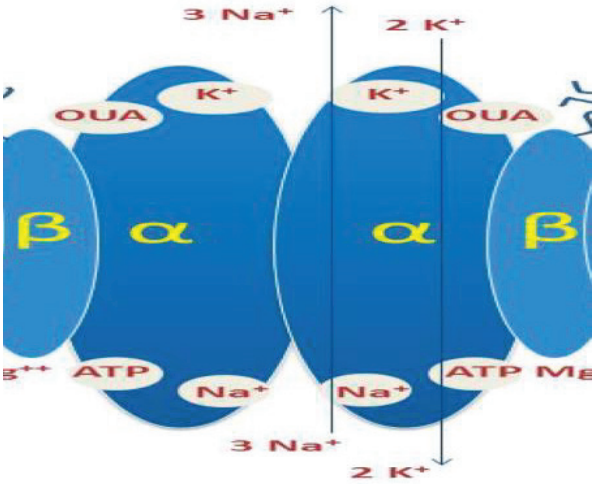
→

Na+ and K leak continuously through leakage channels in the membrane along their concentration gradient that will disturb their normal distribution

→

The Na- to drive Na+ back to out of the cell and pump K back into the cell , against their concentration gradient.

- **Mechanism of action:**
- Na-K pump is a carrier protein formed of a complex of two separate globular proteins:
  - The larger one called the 'a' subunit.
  - The smaller one; the 'b' subunit.

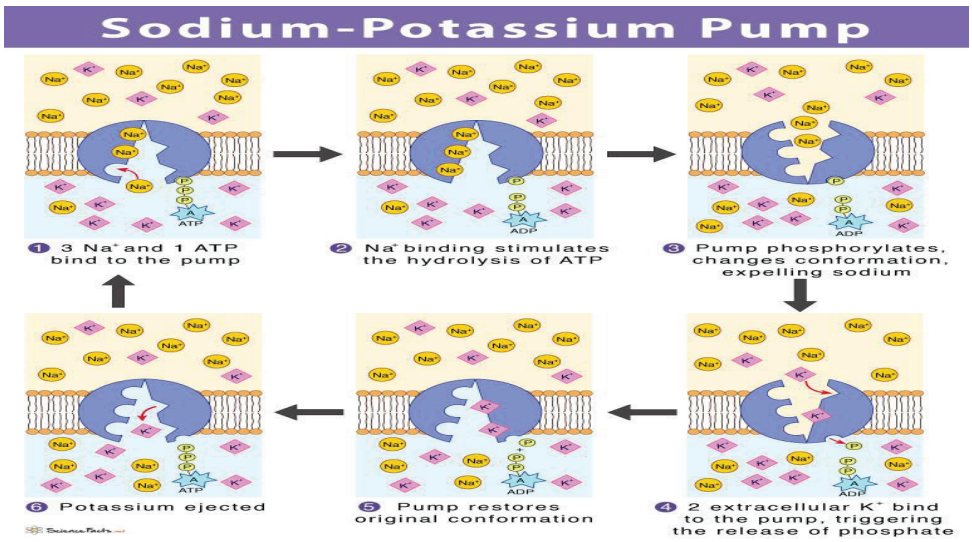


- **The larger protein has three specific features:**
  1. It has 3 receptor sites for binding sodium ions on the inner surface.
  2. It has 2 receptor sites for potassium ions on the outside surface.
  3. It has an ATPase activity.

When potassium ions bind on the outside of the carrier protein and .the sodium ions bind on the inside →the ATPase activated

This then cleaves one molecule of ATP →Spliting it and Liberate a high energy phosphate bond.

This energy causes a conformational change in the carrier molecule → Move the sodium ions to the outside and potassium ions to the inside



- **Electrogenic Nature of the Na-K Pump:**
  - The fact that the Na-K pump moves 3 Na ions to the exterior for every 2 K ions to the interior creates positivity outside the cell and negativity on the inside (membrane potential).
  - Na+-K pump is said to be electrogenic because it creates an electrical potential across the cell membrane.

- **Importance of the Na+-K+ Pump:**
  1. This pump is responsible for maintaining the sodium and potassium concentration differences across the cell membrane.
  2. Maintenance of intracellular potassium is necessary for protein metabolism.
  3. It keeps the osmotic equilibrium and controls cell volume.
  4. It maintains a negative electrical voltage inside the cells.

B. Secondary Active Transport

Mechanism:

- Involves a carrier in the lipid layer of the membrane with two binding sites:

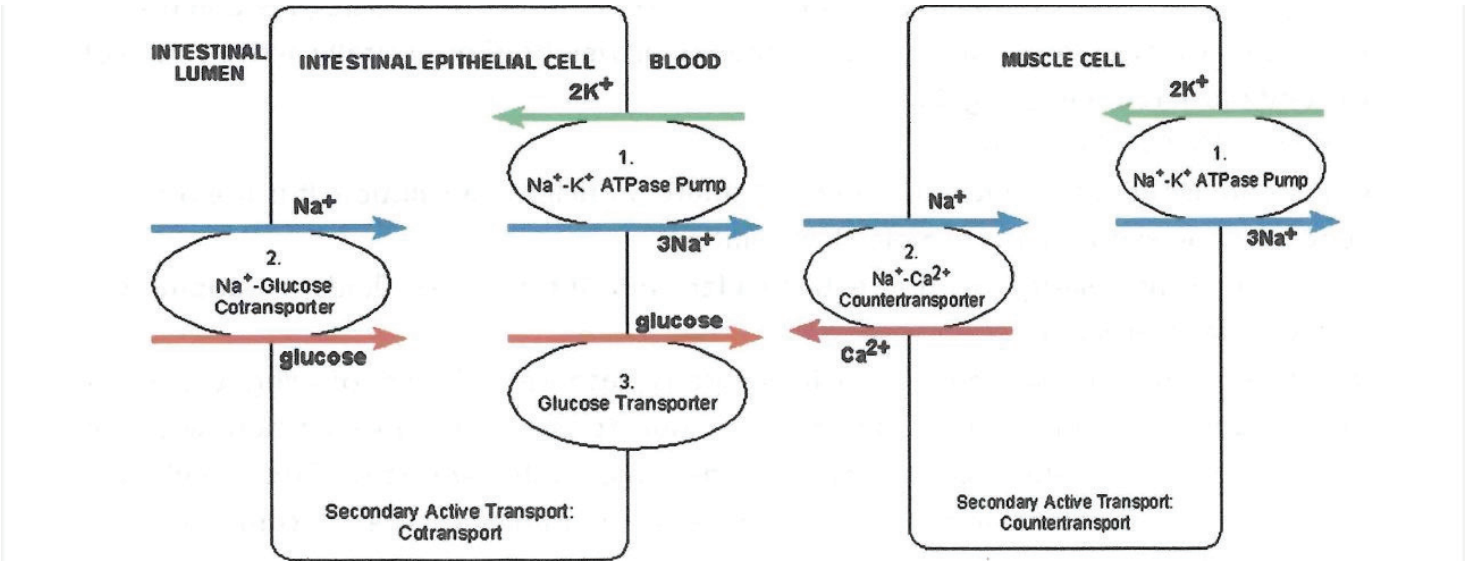
  Site 1: For one sodium ion moving with its concentration gradient.

  Site 2: For another molecule (e.g., glucose, galactose, or amino acids) moving against its electrochemical gradient.

- **Types of Secondary Active Transport**

Type	Description	Example
Symport System (Co-transport)	Two transported substances move in the same direction	▪ Sodium-Glucose co-transport, ▪ Sodium-amino acids co-transport
Antiport System (Counter-transport)	Two transported substances move in opposite directions.	▪ Sodium-Calcium counter-transport ▪ Sodium-Hydrogen counter-transport

The energy supplied for glucose, galactose or a.a. in this process comes from the movement of the sodium along its electrochemical (concentration) gradient.



N.B. Glucose transport

1. Facilitated diffusion through GLUT (Glu transporters) in most tissues
2. Secondary active transport through SGLT (sodium- glucose linked transporter) in small intestine and kidneys

Active

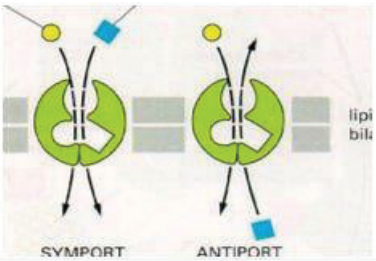
- Against conc gradient from↓ conc to conc↑.
- Additional source of energy derived from the cell.

Primary

- Energy directly from breakdown of ATP or creatine phosphate.
- E.g (Na-K pump).

Secondary

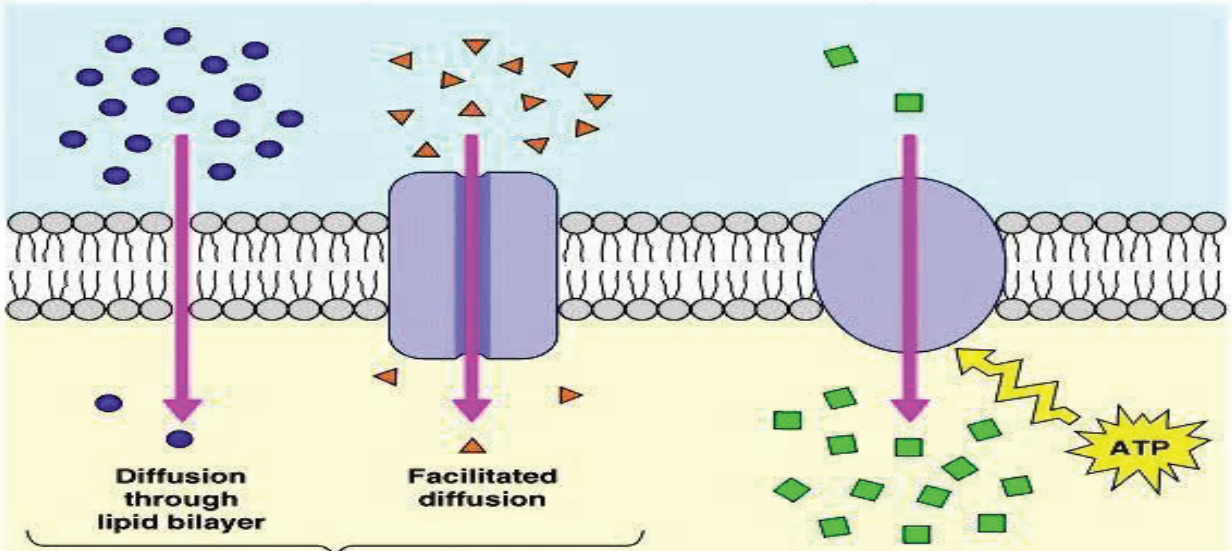
- Energy from movement of sodium with electrochemical gradient.
- Carrier protein has 2 binding sites:
  1) One for Na that moves with conc gradient.
  2) One for other substance that moves against conc gradient.eg (glucose, galactose, AAs).



Types

Symport (co-transport)	Antiport (counter-transport)
2 substances at one direction 2×1	2 substances at different direction 2×2
e.g (sodium-glucose, sodium-AA)	e.g (sodium-Calcium, sodium-hydrogen)

Figure 8.14 Review: A comparison of passive and active transport



Resting Membrane Potential

Polarized State

- **Normal Value:**
  - Resting membrane potential ranges from - 50 to - 100 millivolts (mV), depending on cell type. Hence, all cells are said to be polarized.
  - The minus sign before the voltage indicates that the inside of the cell is negative compared to its outside.
- **Causes of resting membrane potential:**

1. Selective permeability across the cell membrane:

- **Ions distribution:**
  a. K and protein anions predominate inside body cells
  b. The extracellular fluid contains relatively more Na+ , Cl - and HCO3 -

N.B: Cl does not contribute to the resting membrane potential because its entry is resisted by the negative charge of the interior due to protein anions.

Ion/Aspect	Permeability	Effect on Membrane Potential
K+ (Potassium)	Permeable (due to leakage channels)	Diffuses out, making the interior more negative
Na+ (Sodium)	Low permeability	Attracted into the cell by its concentration gradient (but permeability less than k)
Protein Anions	Absolutely impermeable	Unable to leave, contributing to a more negative interior

2. Active Na+ -K ± pump.

Test yourself!

1. Which of the following molecules can diffuse through the cell membrane by simple diffusion?

A) Proteins
B) Glucose
C) Oxygen

2. What factor does NOT affect the rate of simple diffusion?

A) Surface area of the membrane
B) Concentration gradient
C) Electrical gradient
D) ATP availability

3. Which of the following statements is true about facilitated diffusion?

A) It requires energy from ATP.
B) It occurs through lipid bilayers.
C) It involves carrier proteins.
D) It transports substances against their concentration gradient.

4. Which type of channel is continuously open?

A) Gated channel
B) Leak channel
C) Voltage-gated channel
D) Ligand-gated channel

5. What type of transport involves moving substances against their concentration gradient ?

A) Passive Transport
B) Simple Diffusion
C) Active Transport
D) Osmosis

6. The sodium-potassium pump is an example of:

A) Secondary Active Transport
B) Primary Active Transport
C) Facilitated Diffusion
D) Simple Diffusion

7. In secondary active transport, what is the role of sodium ions in the symport system?

A) They move against their concentration gradient.
B) They move with their concentration gradient.
C) They are not involved in the transport process.
D) They provide energy directly from ATP.

8. What is an example of a molecule transported by facilitated diffusion?

A) Oxygen
B) Glucose
C) Sodium ions
D) Carbon dioxide

9. Which factor increases the permeability of the membrane?

A) Increased thickness of the membrane
B) Decreased number of channels
C) Higher molecular weight of the diffusing substance
D) Higher temperature

10. Which of the following statements about passive transport is true?

A) It requires cellular energy.
B) It moves substances against their concentration gradient.
C) It includes simple and facilitated diffusion.
D) It only occurs in lipid-soluble molecules.

11. What is the typical range of resting membrane potential in most cells?

A) +30 to +70 mV
B) -20 to -60 mV
C) -50 to -100 mV
D) -120 to -150 mV

12. Which component is absolutely impermeable to the plasma membrane?

A) Na+
B) Cl-
C) K+
D) Protein anions

13. Which mechanism is primarily responsible for maintaining the resting membrane potential?

A) Simple diffusion
B) Facilitated diffusion
C) Active Na+-K+ pump
D) Osmosis

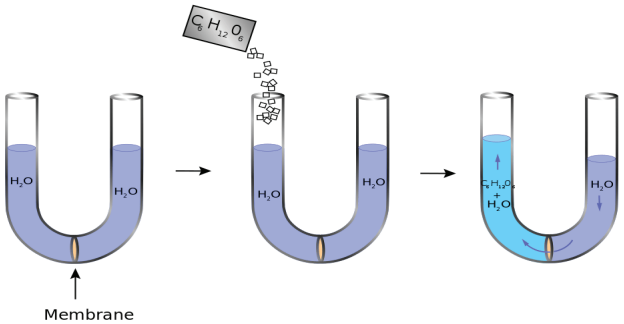
Answers :

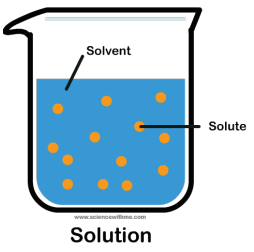
1. C) Oxygen
2. D) ATP availability
3. C) It involves carrier proteins.
4. B) Leak channel
5. C) Active Transport
6. B) Primary Active Transport
7. B) They move with their concentration gradient.
8. B) Glucose
9. D) Higher temperature
10. C) It includes simple and facilitated diffusion.
11. C) -50 to -100 mV
12. D) Protein anions
13. C) Active Na+-K+ pump

Body fluid exchange

- Movement of water & ions across cell membrane occurs by diffusion or active transport.
- The exchange of body fluids is affected by two major forces: **osmosis & filtration.**

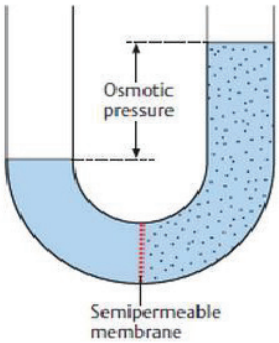
	Filtration	Osmosis
Definition	Forces water and solutes through a membrane or capillary wall by hydrostatic pressure	Passive diffusion of a solvent, such as water, through a selectively permeable membrane
Transport Type	Passive transport	Passive transport
Driving Force	Hydrostatic pressure	Concentration gradient of the solute (osmotic pressure
Solute Movement	Solutes move along with water due to pressure	Solvent (water) moves to the side with higher solute concentration
Membrane Permeability	Dependent on membrane or capillary wall permeability to both water and solutes	Selectively permeable membrane, impermeable to the solute but permeable to the solvent (water)
Determining Factor	pressure gradient that pushes solute-containing fluid (filtrate) from a higher-pressure area to a lower-pressure area.	Number of particles per unit volume of fluid, not the mass of the particles





Osmotic pressure:

- It is the pressure needed in the concentrated solution to prevent water movement from the diluted side.
- It is determined by the number of particles per unit volume of fluid, not by the mass of the particles.



Osmole:

- It is the concentration of a solution in terms of numbers of particles.

→ **One osmole** = 1 gram MW of osmotically active undissociated solute e. g. Glucose.

→ **Osmole** = 1000 milliosmole.

Osmolality:

- **Definition:** Is the number of osmoles per kilogram of solution.
- **Value:** Normal osmolality of the extracellular and intracellular fluids is about 300 milliosmoles/kilogram of water.

N.B: Osmotic imbalances cause cells to swell or shrink

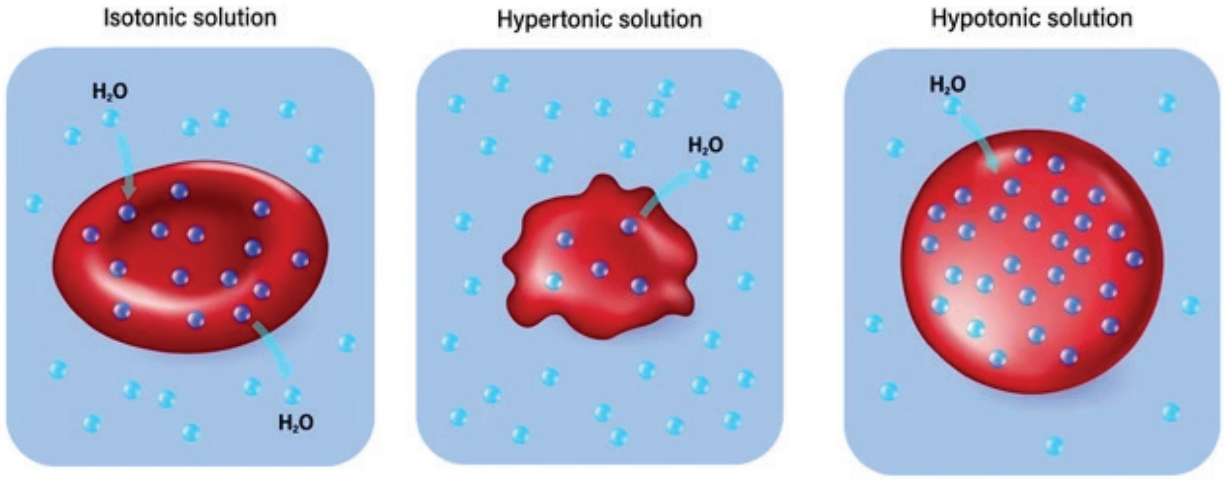
Osmolarity:

- **Definition:** it is the total concentration of all solute particles per liter of solution
- **I.e.**, it is the osmolar concentration - expressed as osmoles/L of solution.

Tonicity:

- **Definition:** It is the ability of a solution to change the shape of cells by alteringtheir internal water volume.
- **Types:**

Aspect	Isotonic Solutions	Hypertonic Solutions	Hypotonic Solutions
Definition	Solutions with the same concentrations of non-penetrating solutes as those found in cells	Solutions with a higher concentration of non-penetrating solutes than seen in the cell	Solutions with a lower concentration of non-penetrating solutes than cells
Examples	0.9% saline 5% glucose	3% Saline 5% Dextrose in 0.9% Saline	0.45% Saline 0.225% Saline Sterile Water
Effect on Cell	Cells retain their normal shape, no loss or gain of water	Cells lose water and shrink	Cells swell and may burst (lyse) as water rushes in
Water Movement	No net movement of water	Water moves out of the cell	Water moves into the cell



Test yourself!

1. Filtration is a process that involves:

a) Active transport of solutes across a membrane

b) Passive movement of water through a membrane

c) Movement of solutes against their concentration gradient

d) Passage of water and solutes through a membrane due to hydrostatic pressure

2. Osmosis is the passive movement of:

a) Solutes across a membrane

b) Water through a selectively permeable membrane

c) Ions from low concentration to high concentration

d) Gases across a membrane

3. Osmosis is primarily driven by:

a) Hydrostatic pressure

b) Osmotic pressure

c) Temperature of the solution

d) Presence of ions in the solution

4. What determines the direction of water movement in osmosis?

a) Hydrostatic pressure

b) Temperature

c) Concentration gradient of solute particles

d) pH of the solution

5. Which of the following statements about osmosis is correct?

a) It involves movement of solutes across a membrane

b) It is independent of the concentration gradient of solutes

c) It is determined by the number of particles per unit volume of fluid

d) It requires energy input

6. Filtration differs from osmosis primarily in that filtration:

a) Requires ATP for movement of particles

b) Involves movement due to osmotic pressure

c) Forces solutes through a membrane by hydrostatic pressure

d) Only allows water to pass through a membrane

7. Which type of solution causes cells to lose water and shrink?

a) Isotonic solution
b) Hypertonic solution
c) Hypotonic solution
d) Saline solution

8. What is the primary determinant of osmotic pressure in a solution?

a) Number of particles per unit volume of fluid
b) Mass of the solute particles
c) Temperature of the solution
d) pH of the solution

9. Which term refers to the number of osmoles per kilogram of solution?

a) Osmolarity
b) Osmotic pressure
c) Osmolality
d) Tonicity

10. What is the normal osmolality of extracellular and intracellular fluids?

a) 100 milliosmoles/kg
b) 500 milliosmoles/kg
c) 300 milliosmoles/kg
d) 700 milliosmoles/kg

11. Which concept describes the ability of a solution to change the shape of cells by altering their internal water volume?

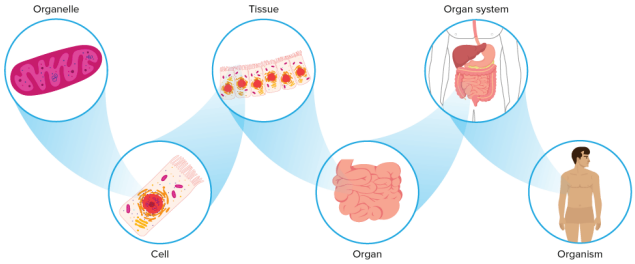
a) Osmotic pressure
b) Osmole
c) Tonicity
d) Osmolality

Answers :

1. d) Passage of water and solutes through a membrane due to hydrostatic pressure
2. b) Water through a selectively permeable membrane
3. b) Osmotic pressure
4. c) Concentration gradient of solute particles
5. c) It is determined by the number of particles per unit volume of fluid
6. c) Forces solutes through a membrane by hydrostatic pressure
7. b) Hypertonic solution
8. a) Number of particles per unit volume of fluid
9. c) Osmolality
10. c) 300 milliosmoles/kg
11. c) Tonicity

Homeostasis

- The human body consists of many systems e.g., cardiovascular, respiratory, nervous etc., each system is made of organs; each organ is made of tissues, which in turn are made up of cells.
- The cell is the living unit of the body.
- Each cell is specifically performing one or few particular functions.



Composition of the human body

1. Water

Component	Description	Amount
Total Body Water (TBW)	▪ Total fluid content in the body ▪ Decreases with age and varies with body fat percentage	▪ 60% of body weight ▪ Example: 40 liters for a 65 kg man
1. Intracellular Fluid (ICF)	Fluid inside the cells	Approximately 25 liters
2. Extracellular Fluid (ECF)	Fluid outside the cells ▪ Interstitial Fluid ▪ Intravascular Fluid (Blood Plasma) ▪ Transcellular Fluid	Approximately 15 liters 12 liters 3 liters 500 ml

Component	Description	Percentage of Body Weight
1. Water	Varies with age and body fat percentage	60%
2. Proteins	Found in all tissues, with the largest amount in skeletal muscles	18%
3. Fats	▪ Main energy stores, found around abdominal viscera, subcutaneous tissues, and in the CNS structure ▪ Phospholipids are part of cell membranes	15%
4. Minerals	▪ Present in relatively small quantities, except for calcium ▪ Different concentrations in intracellular vs. extracellular fluid	7%

	Extracellular fluid	Intracellular fluid
Cations (mmol/L)		
Na^+	145	10
K^+	4	145
Ca^{++}	5	1
Mg^{++}	2	40
Total (+)	**156**	**196**
Anions (mmol/L)		
Cl^-	105	3
HCO_3^-	28	10
Protein	17	45
HPO_4^{--}	6	138
Total (-)	**156**	**196**

Category	Extracellular	Intracellular
Most Abundant Ions	Sodium - Chloride	Potassium - Phosphate - Proteins
Least Abundant Ions	Magnesium - Phosphate	Calcium - Chloride

The internal environment:

- **Definition:**
  - All cells are surrounded by the same environment (the extracellular fluid) which contains the ions and nutrients needed by the cells to maintain cell life.
  - There is continuous exchange between the intravascular and interstitial fluid to keep the internal environment constant.

Table (2): Important constituents and physical characteristics of extracellular fluid:

	Normal Value	Normal Range	Approximate Short-Term Nonlethal Limit	Unit
Oxygen (venous)	40	35-45	10-1000	mm Hg
Carbon dioxide (venous)	45	35-45	5-80	mm Hg
Sodium ion	142	138-146	115-175	mmol/L
Potassium ion	4.2	3.8-5.0	1.5-9.0	mmol/L
Calcium ion	1.2	1.0-1.4	0.5-2.0	mmol/L
Chloride ion	106	103-112	70-130	mmol/L
Bicarbonate ion	24	24-32	8-45	mmol/L
Glucose	90	75-95	20-1500	mg/dl
Body temperature	98.4 (37.0)	98-98.8 (36.6 - 37.1)	65-18.3) 110-43.3)	°F (°C)
Acid-base	7.4	7.3-7.5	6.9-8.0	pH

- **Normal ranges:**

- Note the narrowness of the normal range for each one.
- Values outside these ranges are often caused by illness, disease, injury, or major environmental challenges, and some **abnormalities may cause death:**
  1. An increase in the body temperature of only 11°F (7°C) above normal can lead to a vicious cycle of increasing cellular metabolism that destroys the cells.
  2. A normal pH value is 7.4. Lethal values only about 0.5 on either side of normal.

Cells are capable of living and performing their special functions as long as the proper concentrations of oxygen, glucose, different ions, amino acids, fatty substances, and other constituents are available in this internal environment

Homeostasis:

- **Definition:** is the ability of the body to maintain constant conditions in its internal environment in spite of the changes in the surroundings.

Homeostatic Control Mechanism:

- **Definition:** The homeostatic mechanisms are the regulatory mechanisms that tend to correct any deviation from normal in response to changes in the external or internal environment.

- Each cell benefits from homeostasis, and in turn, each cell contributes its share toward the maintenance of constant internal environment e.g body temperature.
- If one or more systems of the body lose this function, all the cells of the body suffer.
- Moderate dysfunction leads to sickness whereas extreme dysfunction leads to death.

The control systems of the body:

- Communication within the body is essential for homeostasis.
- **The body depends mainly on two major control systems for the regulation of all its functions:**

1. The nervous system:

- Responsible to the functions that need rapidity of execution: e.g., applying a hot object to the hand causes immediate flexion of the arm to withdraw it from such harmful hot object.

- **The nervous system is composed of three major parts:**

Component	Description
1. Sensory Input	Detects body and environmental states.
2. Central Nervous System	▪ **Brain:** Processes information, generates thoughts, coordinates responses. ▪ **Spinal Cord:** Transmits signals between the brain and body, controls reflexes.
3. Motor Output	Executes actions based on sensory input and CNS processing.

- An important segment of the nervous system is called autonomic system. It controls subconsciously many functions of the internal organs.

2. The Endocrine system

- Composed of many endocrine glands and several organs and tissues that secrete hormones into the blood stream.
- Hormones are transported through ECF to different body organs to help regulate cellular function.
- Endocrine system is concerned with the functions that do not need rapidity of execution

  → **e.g.:**

  1. Thyroid hormone increases rate of chemical reactions in all cells
  2. Insulin controls glucose metabolism

N.B: Many interrelationships exist between the endocrine and nervous system

Characteristics of Control Systems:

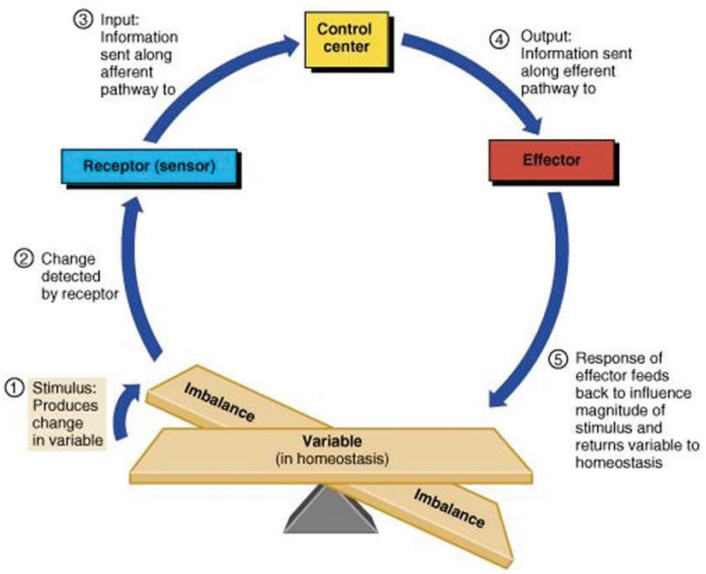
- All homeostatic control mechanisms have at least three main components:
- Stimulus → receptor (first component) → afferent pathway (nerve) → center (second component) → efferent pathway (nerve) → effector (third component) → response (feedback, which may be positive or negative)

Component	Description	Function
Receptor	▪ Monitors the environment for stimuli ▪ Responds to changes (stimuli) by sending input along the afferent pathway	▪ Initiates sensory input
Control Center	▪ Analyzes input received from receptors ▪ Processes information and makes decisions	▪ Determines and coordinates appropriate responses
Effector	▪ Receives information from the control center along the efferent pathway ▪ Produces responses that alter conditions in the internal or external environment	▪ Executes responses

The result of the response is feedback:

1. Depressing it (negative feedback): so that the whole control mechanism is shut off.

2. Enhancing it (positive feedback): so that the reaction continues at an even faster rate.



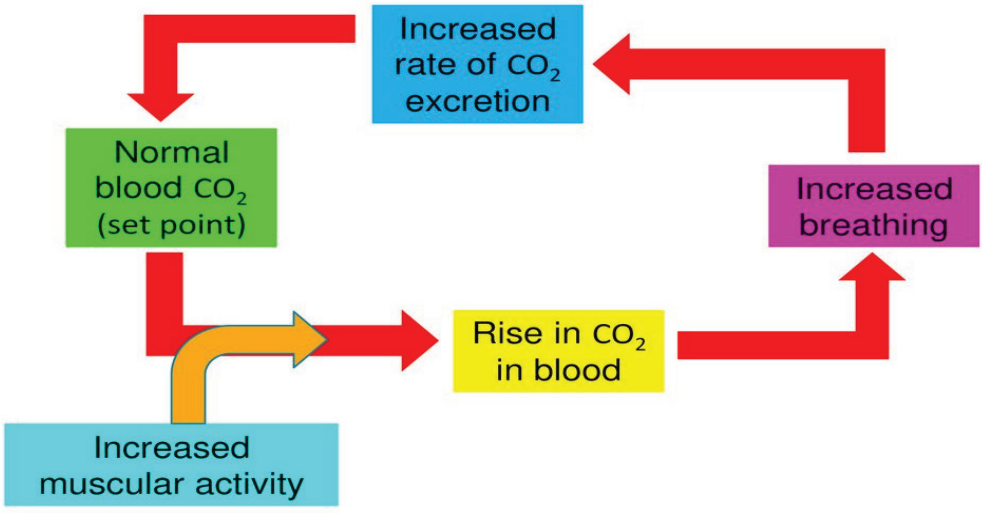
Negative Feedback Mechanisms:

Definition:

- In these systems, the output (response) is opposite to the original stimulus.
- The output shuts off the original stimulus or reduces its intensity.

Importance: have the goal of preventing sudden severe changes within the body.

→**e.g.: CO2 feedback mechanism:** If the concentration of carbon dioxide in the extracellular fluid increases **(due to increase activities of the cells)** → it will stimulate the rate of breathing, and the excess of carbon dioxide is washed out → This, in turn, decreases the extracellular fluid carbon dioxide concentration.



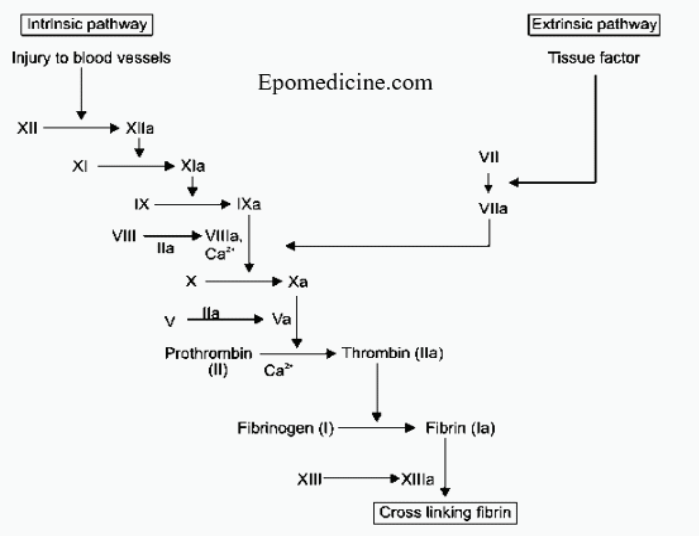
Positive Feedback Mechanisms:

- **Definition:** In positive feedback mechanisms, the response enhances the original stimulus.
- The response proceeds in the same direction of the stimulus i.e., stimulates two types: **"vicious cycle" & "cascades".**

1. Cascade positive feedback:

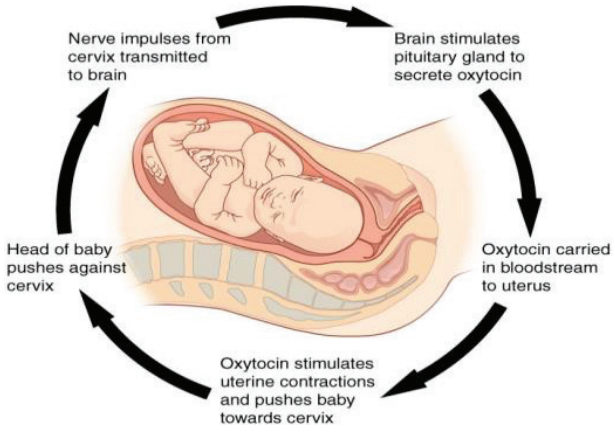
- **Blood clotting:**

→ **Mechanism:** Multiple enzymes (clotting factors) are activated within clot itself these activated enzymes will act on other inactive enzymes → then activate them, and so on more blood clotting until bleeding stopped.



2. Vicious circle positive feedback:

- Childbirth when uterine contractions become strong enough to push the baby's head through the cervix → stretched cervix → sends signals to the pituitary gland → secrete the oxytocin hormone → circulates in the blood → reach the uterine muscles → causing even more powerful contractions.
- So uterine contractions stretch cervix, and cervical stretch causes stronger contractions. When this process becomes powerful enough, baby will born.



N.B: In contrast to negative feedback controls, which maintain physiological function within narrow ranges, positive feedback mechanisms control infrequent events that do not require continuous adjustments.

Comparison of Negative and Positive Feedback Mechanisms

	Negative Feedback Mechanisms	Positive Feedback Mechanisms
Definition	▪ Output (response) is opposite to the original stimulus. ▪ Output shuts off or reduces the intensity of the stimulus.	▪ Response enhances the original stimulus. ▪ Response proceeds in the same direction as the stimulus.
Purpose	▪ Maintains homeostasis by counteracting changes.	▪ Amplifies or accelerates a process to completion.
Example	▪ **CO2 feedback mechanism:** Increased CO2 levels stimulate increased breathing to decrease CO2 levels.	▪ **Blood clotting:** Activation of clotting factors leads to further activation until clot formation is complete. ▪ **Childbirth:** Uterine contractions stimulate release of oxytocin, which further increases contractions until birth.
Characteristics	▪ Stabilizes internal conditions within a narrow range. ▪ Output opposes the initial change to maintain equilibrium.	▪ Often leads to a rapid and dramatic change. ▪ Output reinforces the stimulus to achieve a specific outcome.
Common in	▪ Regulation of body temperature, blood pressure and pH levels	▪ Childbirth, blood clotting, lactation (milk production).

Homeostatic Imbalance:

- Homeostasis is so important that most of the diseases can be regarded as a result of its disturbance, a condition called homeostatic imbalance.

Integration of body functions

There is a functional relationship between the various systems of the body:

A good example for this integration is during muscular exercise, many systems act to increase the oxygen needs of the active muscles and to remove the waste products as CO2 and the heat liberated during exercise, to enable the muscles to act for a long time without fatigue, as follow:

1. Cardiovascular changes: The functions of the heart are increased.

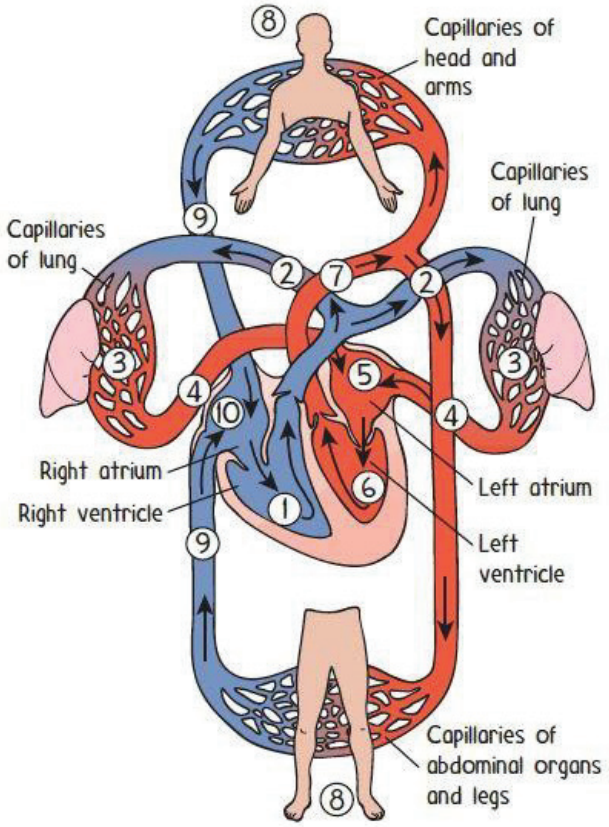
- The blood that carries the oxygen and nutrients to the active muscles and removes the waste product from it is also increased

2. Respiratory changes: There is increase rate of respiration.

- This will lead to increase oxygen delivered to the body and wash excess CO2.

3. Temperature regulation: During muscular exercise the heat production is increased, which stimulates the heat losses mechanisms.

4. Muscle coordination: During muscular exercise the adjustment and smoothness of movements are obtained via certain parts in the brain.



Test yourself!

1. Which component of the nervous system is responsible for coordinating responses to stimuli and processing information?

A) Receptor
B) Motor neuron
C) Central nervous system
D) Effector

2. What is the primary function of the effector in a control system?

A) Detects stimuli and sends information to the control center.
B) Receives signals from the control center and executes responses.
C) Analyzes input received from receptors.
D) Initiates changes to counteract deviations from set points.

3. What is the distinguishing feature of positive feedback mechanisms?

A) They stabilize internal conditions within narrow ranges.
B) They initiate responses opposite to the stimulus.
C) They amplify the original stimulus, leading to rapid changes.
D) They maintain equilibrium in biological systems.

4. Which of the following best describes negative feedback mechanisms in biological systems?

A) Enhances the original stimulus.
B) Counteracts changes and maintains stability.
C) Amplifies responses until a specific outcome is achieved.
D) Initiates rapid and dramatic changes.

5. What is the primary purpose of positive feedback mechanisms in the body?

A) To stabilize internal conditions.
B) To reduce the intensity of a stimulus.
C) To amplify or accelerate a process.

6. Which example best illustrates a negative feedback mechanism in the human body?

A) Blood clotting cascade.
B) Childbirth contractions.
C) Regulation of body temperature.
D) Milk production during lactation.

Answers :

1. C) Central nervous system
2. B) Receives signals from the control center and executes responses.
3. C) They amplify the original stimulus, leading to rapid changes.
4. B) Counteracts changes and maintains stability.
5. C) To amplify or accelerate a process.
6. C) Regulation of body temperature.

The Nervous System

- In the human body, there are two main control systems: the endocrine system and the nervous system, both coordinate the functions of various systems in order to maintain homeostasis

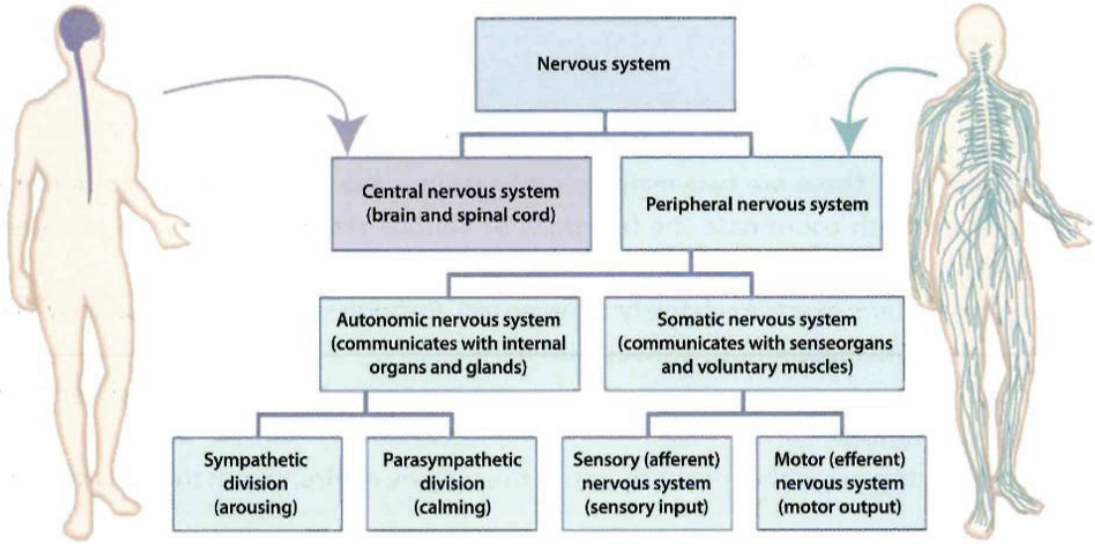
	Endocrine System	Nervous System
Description	Controls via hormones that regulate growth and metabolic processes.	Controls through rapid transmission of electrical signals.
Control Speed	Relatively slow	Rapid
Functions	▪ Regulates growth and metabolic activities within cells.	▪ **Sensory Function:** Detects changes in body and environment. ▪ **Integrative Function:** Processes and interprets sensory information. ▪ **Motor Function:** Initiates muscular contractions and glandular secretions.

Classification:

1. Physiological (functional) classification of nervous system:

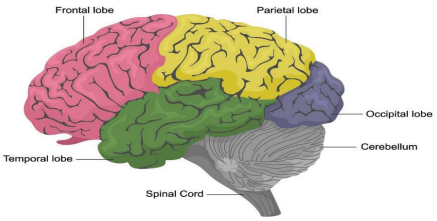
a. Somatic nervous system control body voluntary movements of skeletal muscles
b. Autonomic nervous system control involuntary of viscera & glands

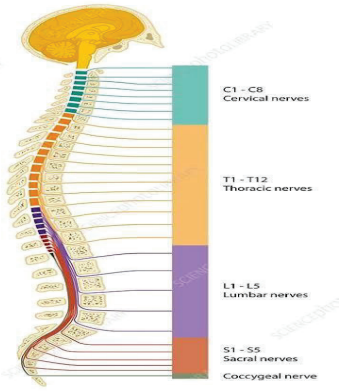
2. Anatomical classification of the nervous system:



A. Central nervous system (CNS):

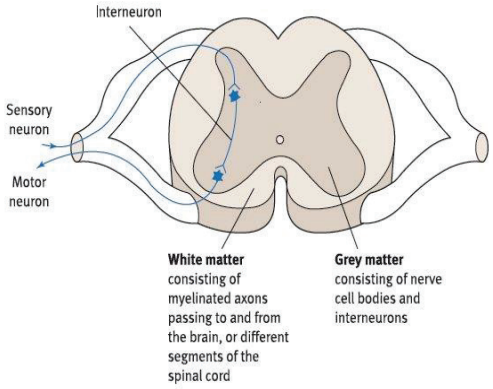
a- Brain

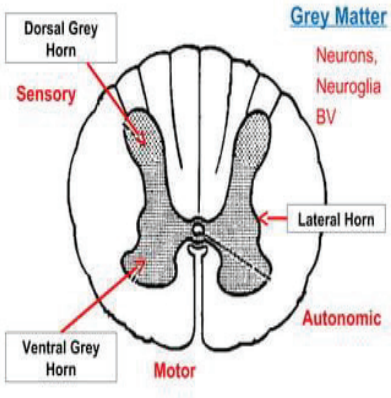




b- Spinal cord

- In cross section, the spinal cord shows a central butter fly-shaped area grey matter with 3 projections called horns: dorsal, lateral and ventral.
- The grey matter is surrounded by white matter, which consists of groups of myelinated axons.
- **These groups of fibers run longitudinally through the cord :**
  - Some descending to relay information from the brain to the spinal cord.
  - Other ascending to transmit information to the cortex.





- The spinal cord is divided into 31 segments with a pair of spinal nerve arising from each segment.
- **Each spinal nerve arises from the spinal cord by 2 roots:**

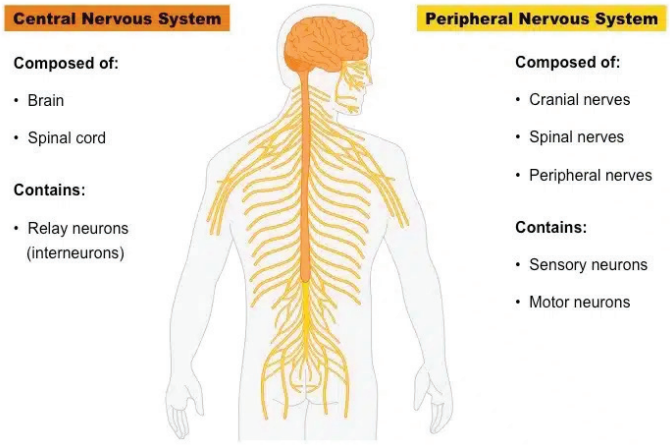
Feature	Dorsal (Afferent Sensory) Root	Ventral (Efferent Motor) Root
Function	Carries sensory information from the body to the spinal cord.	Carries motor information from the spinal cord to the muscles.
Origin	Sensory receptors in the body	Ventral horn of the spinal cord
Termination	Dorsal horn of the spinal cord	Travels to the body and forms connections (synapses) with skeletal muscles.
Cell Body Location	Dorsal root ganglia (outside the spinal cord)	Ventral horn (inside the spinal cord)

Synapse:

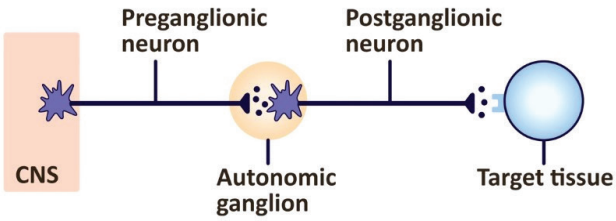
It is the site of contact between 2 neurons i.e. the site of contact between the axon terminals of one neuron and cell body or dendrites of another neuron. (there is no cytoplasmic continuity between neurons).

B. Peripheral nervous system: (peripheral nerves arise from CNS)

Cranial Nerves	12 pairs arising mostly from the brain stem.
Spinal Nerves	31 pairs arising from the spinal cord, one pair for each segment.



- **There are two major categories of motor neurons:**
  1. **Somatic motor neurons:** have their cell bodies within the CNS (anterior horn cell) and send axons to skeletal muscles, which are usually under voluntary control. It is thick myelinated type Aa fiber with fast conduction about 100m/sec
  2. **Autonomic motor neurons:** involves two neurons in the efferent pathway: preganglionic and post ganglionic neurons with an autonomic ganglia in between.

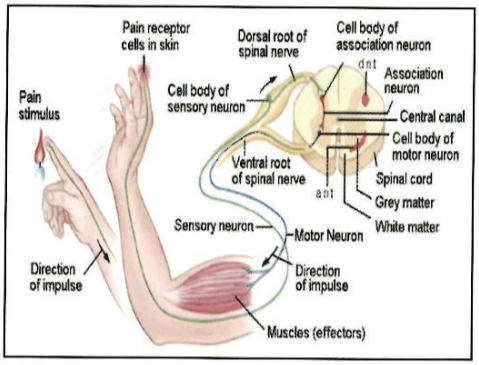


Neurons/ Nerve cell

- **Definition:** (The structural unit of the nervous system):

1. A (myelinated) ➔ 100 m/s
2. B (myelinated) ➔ 10 m/s
3. C (unmyelinated) ➔ 1 m/s

Reflex action



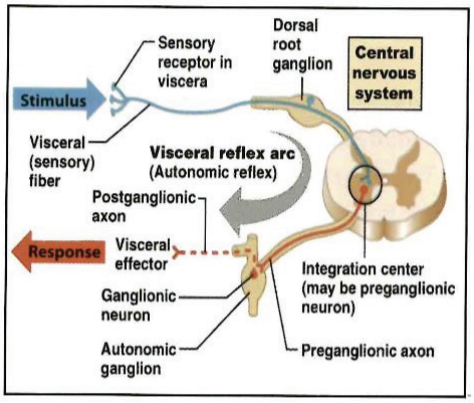
- **Definition:**
  - Is an unavoidable beneficial inborn response brought about by a stimulus (a sudden change of the external or internal environment)
  - The functional unit of the nervous system.
- **Types of reflex action :**

1. Somatic reflex action:

- If the responding tissue is skeletal muscle.

2. Autonomic reflex action:

- Concerned with reflexes of internal organs or viscera such as gastrointestinal tract, urinary bladder ... etc.



Reflex Arc

- **Components**

1. Receptor
2. Afferent neuron (sensory neuron carries impulse from receptors to central nervous system)
3. Center
4. Efferent (motor neuron carries impulses from the CNS to the effector organ)
5. Effector organ

	Somatic	Autonomic
1- Receptor	Skin	The viscus (organ itself)
2- Afferent	Identical in both arcs	
3- Center	Anterior horn cell	Lateral horn cell
4- Efferent neuron	Somatic motor neuron Thick myelinated type Aα → fast conduction velocity (100m/sec)	**Two neurons, with a synaptic connection (ganglia)** ▪ Preganglionic neuron → preganglionic fibers (thin myelinated type B, with conduction 10m/sec) ▪ Postganglionic neuron → postganglionic fibers (unmyelinated C fiber, with conduction 1m/sec)
5- Effector organ	Skeletal muscle.	plain, cardiac muscles and gland

The Autonomic Nervous System

- **Physiological (Functional) classification of ANS:**
  a. The sympathetic: thoracolumbar outflow
  b. The parasympathetic: craniosacral outflow (cranial & sacral outflows have complementary physiological action).
- **Anatomical classification (divisions) of ANS:**

Preganglionic neuron of the ANS starts in:

1. Cranial autonomic outflow:

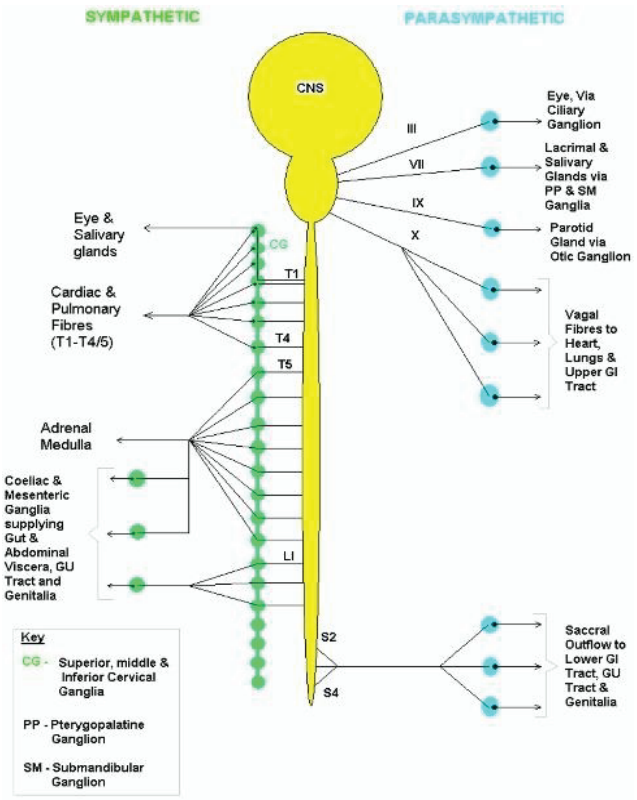
- From the midbrain, medulla oblongata, pons.
- Cranial nerves III, VII, IX & X.

2. Thoracolumbar autonomic outflow:

- From T1 to L2.

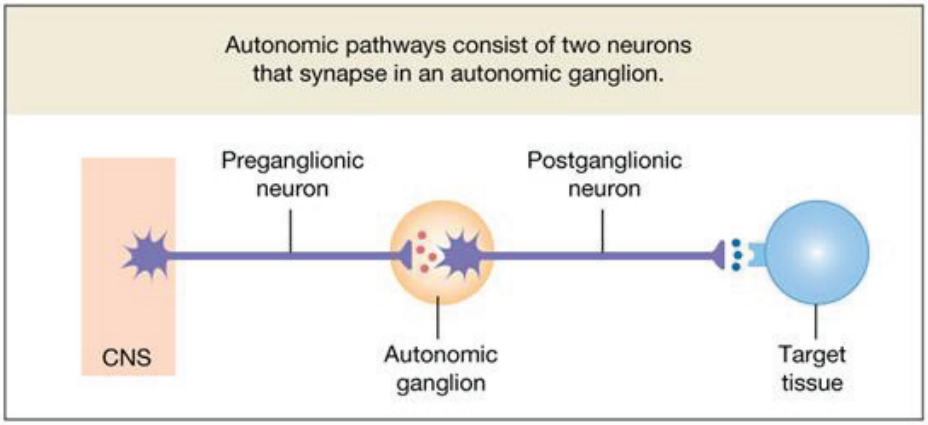
3. The sacral autonomic outflow:

- S 2,3,4.



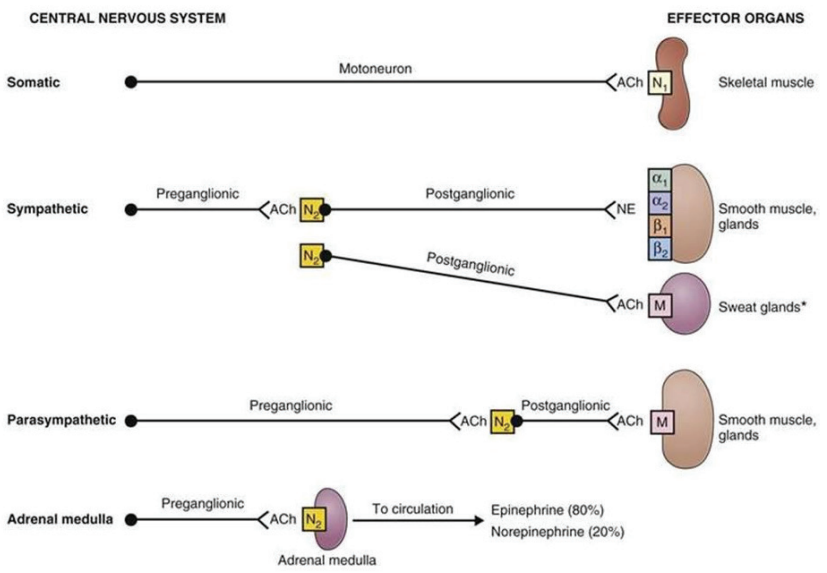
Autonomic ganglia:

- **Definition:** Aggregation of cell bodies of neurons outside the CNS.



- The peripheral efferent portions of the autonomic nervous syst em are made up of preganglionic and postganglionic neurons.
- **The preganglionic neuron:**
  - It has its cell body in the gray matter of the brain or spinal cord (lateral horn cell). The axon of this neuron does not directly innervate the effector organ but instead synapses with a second neuron within an autonomic ganglion.
  - This neuron is thin myelinated type B fiber with a conduction velocity of about 10 m/sec.

- **The postganglionic neuron**
  - Is the second neuron in this pathway, which has an axon that extends from the autonomic ganglion to an effector organ, where it synapses with its target tissue.
  - It is thin unmyelinated C fiber with a velocity of conduction about 1m/sec.



- **Classification**

	Lateral Paravertebral Ganglia	Collateral Prevertebral Ganglia	Terminal Peripheral Ganglia
Site	On each side of the vertebral column → sympathetic chains (2 in number) Located near the spinal cord - contains one ganglion for each segmental nerve except in the cervical region → ganglia fused to form three ganglia (the superior, middle and inferior cervical ganglia)	Between the sympathetic chain and the organ of supply Coeliac, superior And inferior Mesenteric ganglia	Near or embedded in the innervated organs
Relay of	Preganglionic sympathetic fibers of head, neck, thorax	Preganglionic sympathetic fibers of abdominal and pelvic viscera	Preganglionic parasympathetic fibers
Preganglionic fiber	Short as the ganglia is near from spinal cord	In-between	Long as the ganglia is far from spinal cord
Postganglionic fiber	Long as the ganglia is far from organ	In-between	Short as the ganglia is near or sometimes on the organ

- **Functions of the autonomic ganglia:**

1. Act as distributing centers:

a. Sympathetic system preganglionic fibers synapse → activate many postganglionic neurons → generalized sympathetic effects over wide areas of the body (widespread distribution of impulse)

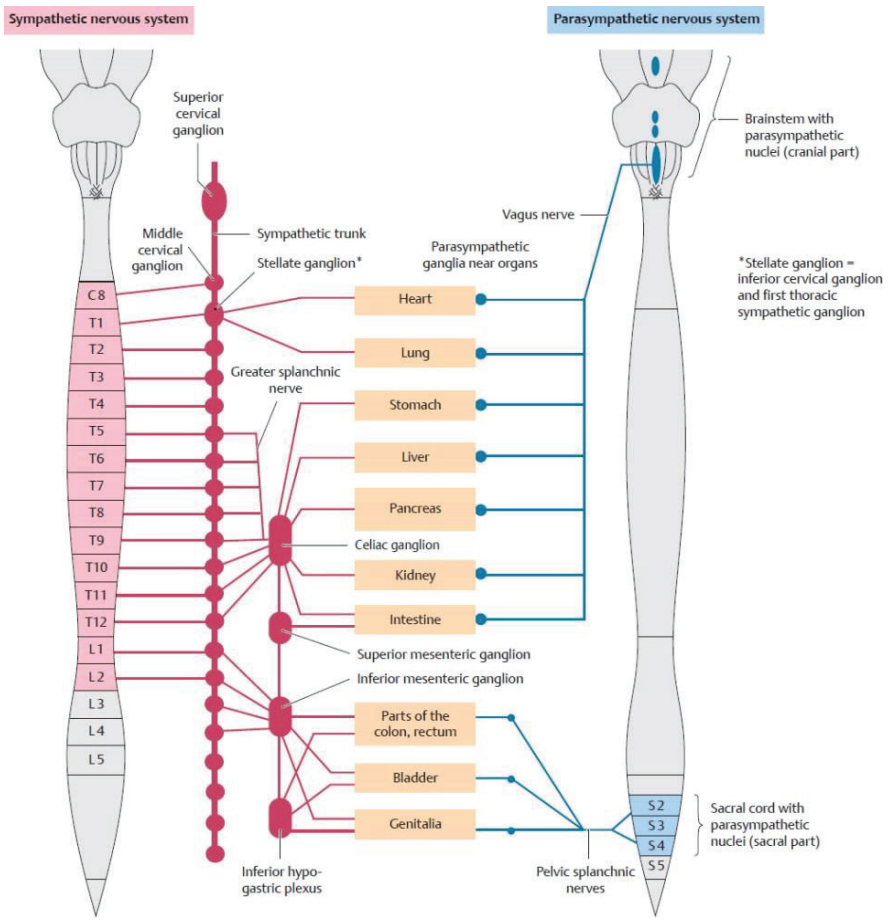
b. Parasympathetic system Preganglionic fibers synapse → activate only few postganglionic neurons → localized discrete parasympathetic activities.

2. Site of relay (synapse): Autonomic ganglia are cell stations for relay of preganglionic fibers coming from CNS.

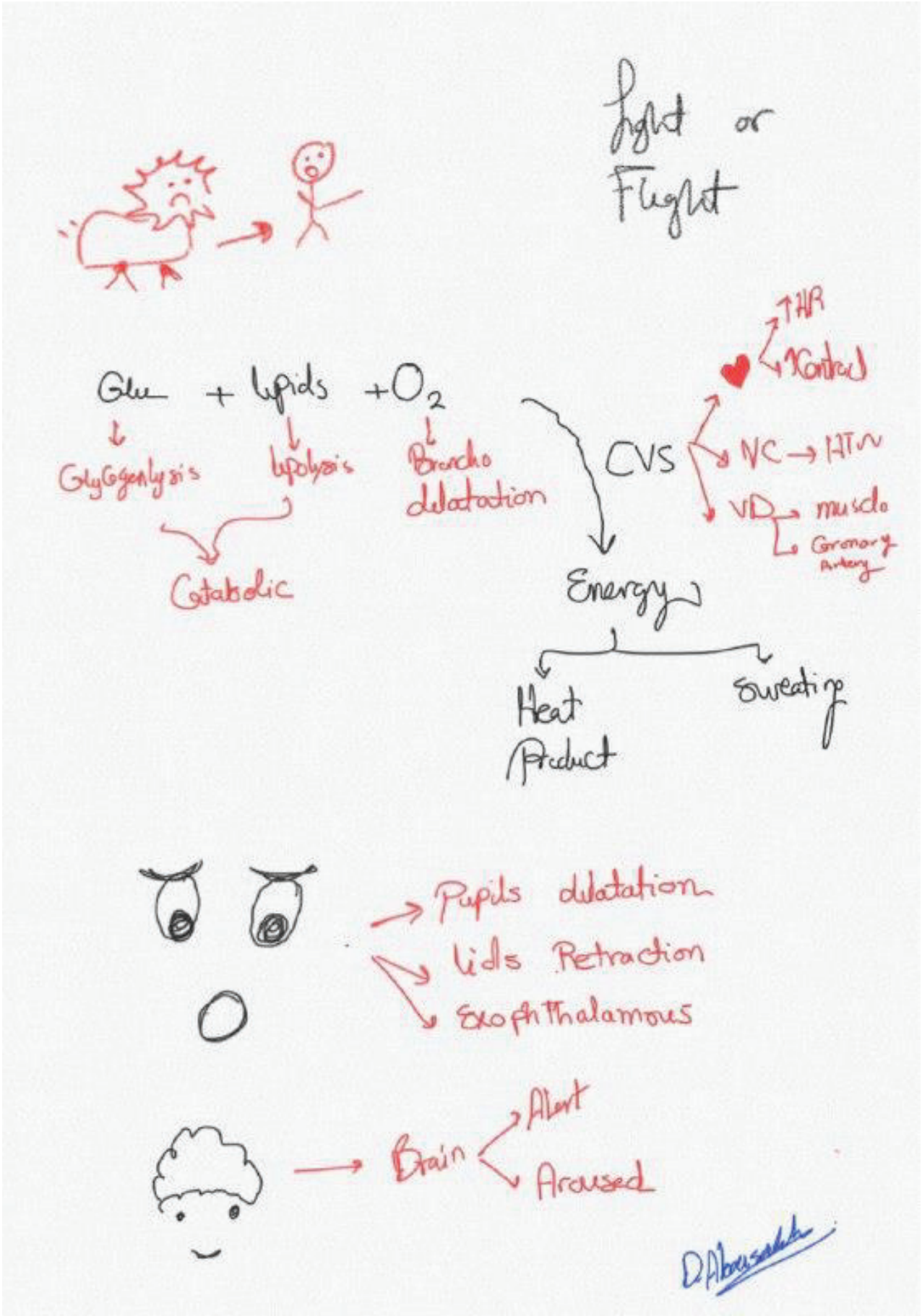
3. Release of Chemical transmitter:

- Acetylcholine is the mediator at all preganglionic endings (sympathetic and parasympathetic).
- It is responsible for transmission of nerve impulse from preganglionic to postganglionic neurons (synaptic transmission).

N.B: Each preganglionic fiber relays once only, though it may pass through several ganglia.



Sympathetic Nervous System



1. Head & neck

- Center (LHC)
- Ganglia (sympathetic chain)
- Post ganglionic fibers Pass along the branches of the carotid artery.

1. Eye	**Motor to all muscles** ▪ Dilatation of pupil (mydriasis) ▪ Retraction of eye lids → wide palpebral fissure ▪ Protrusion of eye ball (exophthalmos) Lacrimal gland Blood vessels → vasoconstriction → atrophic or no secretions
2. Salivary glands	▪ Trophic secretory fibers → saliva (viscid, small in volume, rich in organic matter) ▪ Blood vessels → vasoconstriction
3. Skin	1. Erector pilae muscle → erect hair in animal 2. Sweat glands → secretory sweat 3. Cutaneous and deep vessels motor → vasoconstriction
4. Cerebral vessels	Under normal physiological conditions sympathetic has little influence on cerebral autoregulation. Its role is more evident under pathological conditions as hypertension. Weak VC

N.B: Horner's syndrome:

- Sympathetic trunk is damaged Results in
  1. Partial ptosis (drooping or falling of the upper eyelid)
  2. Miosis (constricted pupil)
  3. Facial anhidrosis (absence of sweating)
  4. Enophthalamus

2. Thorax

- Center (LHC)
- Ganglia (sympathetic chain)

1. Heart:	1. Cardiac muscle properties → increase of heart rate and force of contraction 2. Coronaries Excitation Vasodilator → increase the blood supply and O2 to the cardiac muscle
2. Lung:	1. Plain (smooth) muscle of the bronchi and bronchioles Inhibitory → broncho-dilatation. 2. The pulmonary blood vessels → Slight vasoconstriction

3. Abdomen &Pelvis

- Center (LHC)
- Ganglia: collateral ganglion

1. Abdomen (greater splanchnic nerve)

N.B: The term splanchnic is usually used to describe organs in the abdominal cavity (visceral organs).

1. Visceral Blood vessels	Vasoconstriction
2. Smooth muscles & sphincters of wall of stomach, SI & proximal ½ of colon	Inhibitory of smooth muscles and motor to sphincters → food retention.
3. Smooth muscles & sphincters of Oddi o of GB:	Inhibitory of smooth muscles and motor to sphincters → bile retention.
4. Smooth muscles of splenic capsule:	Motor to smooth muscle → contraction → blood rich in RBCs & O2
5. Liver:	Glycogenolytic: conversion of glycogen into glucose → ↑ blood glucose level
6. Adrenal medulla	Secretion of adrenaline and noradrenalin

2. Pelvis (Lesser splanchnic nerve)

1. Visceral Blood vessels	Vasoconstriction
2. Smooth muscle &sphincters of distal half of the colon and rectum	Inhibitory of smooth muscle and motor to internal anal sphincters → feces retention
3. Smooth muscle (detrusor muscle) &sphincters of urinary bladder:	Inhibitory of smooth muscle and motor to internal urethral sphincters → urine retention
4. Smooth muscle of male sex organs (epididymis, ejaculatory ducts, seminal vesicles &prostate)	Motor → ejaculation of semen (in males).
5. Smooth muscle of uterus	Contraction or relaxation depending on the stage of menstrual cycle, the ovarian hormonal level, pregnancy and other factors.

Limbs and muscles

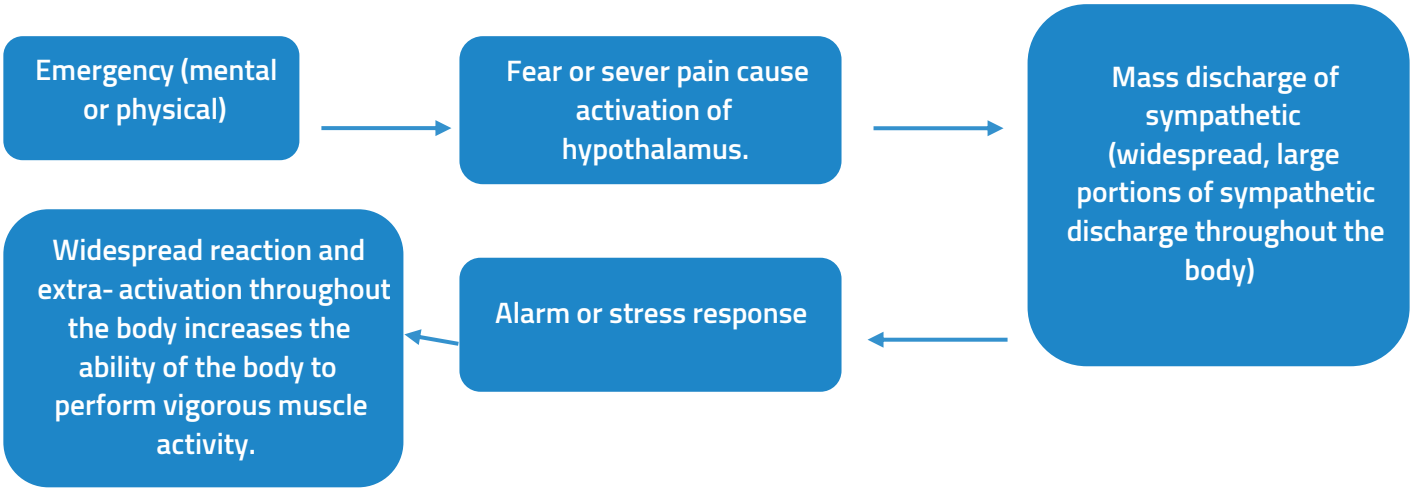
1. Cutaneous blood vessels:	Vasoconstriction
2. Sweat glands:	Secretion of sweat
3. Erector pilae muscle	Motor causing erection of hair in animals
4. Skeletal muscle:	a. Vasodilatation of blood vessels → increase blood flow and O2 supply b. Increase muscle glycogenolysis

Functions of the sympathetic system:

1. Sympathetic tone:

- **Definition:** It is the basal rate of activity of the sympathetic system i.e. under basal conditions the sympathetic system is continuously active and discharge impulses to the innervated organs.
- **Main function:** Tonic sympathetic charge to arterioles maintains arterial pressure → good distribution of blood to tissues.

2. Role of sympathetic nervous system in emergencies i.e., fight and flight i.e. stress:



Functions of the sympathetic system in emergencies:

Eye	Pupil dilation
Central Nervous System	Increased mental activity; reinforces alert state by catecholamines acting on reticular formation
Heart	Increases heart rate and contractility (excitatory effect on cardiac muscle)- Vasodilates coronary arteries (increases blood supply)
Vascular System	Raises blood pressure; redirects blood flow to vital organs and muscles
Lungs	Bronchodilation (relaxes smooth muscle of bronchi and bronchioles)
Spleen	Contracts (releases RBC-rich blood, increasing blood volume and oxygen supply)
Liver	Glycogenolysis (breakdown of glycogen to glucose)- Increases blood glucose levels for energy
Adrenal Medulla	Secretes adrenaline and noradrenaline, enhancing sympathetic response
Skin	Vasoconstriction (reduces bleeding in case of injury)
Sweat Glands	Increases sweat secretion for evaporative heat loss
Muscles	Increases blood flow, oxygen delivery, and glucose supply to muscles
Blood Redistribution	Shifts blood from peripheral organs (skin, spleen) to central organs (heart, CNS, muscles)
Metabolism	Increases cellular metabolism throughout the body

3. **Sympathetic activation may occur in isolated portions of the system:**

   e.g. heat regulation: The sympathetic control sweating and blood flow in the skin without affecting other organs.

Preganglionic fibers on entering the ganglionic chain, a preganglionic fiber may have one of three courses:

1. **Relay in sympathetic chain:** Other preganglionic fibers pass up or down the chain to establish synaptic connections with postganglionic neurons in ganglia belonging to more superior or inferior segments.
2. **May pass without interruption** through the chain into the splanchnic nerves to reach the collateral ganglia (Coeliac, superior, and inferior mesenteric ganglia) then to abdomen and pelvis.

N.B: The postganglionic fibers arising from these ganglia run with the blood vessels to supply the smooth muscle of the abdominal and pelvic viscera, to the glands of the gut, and to the blood vessels of the abdominal viscera.

N.B: The adrenal medulla is the only sympathetic effector organ known to be directly innervated by preganglionic fibers.

3. Directly innervate: Some preganglionic fibers of the splanchnic nerve directly innervate secretory cells of the adrenal medulla.

Test yourself!

1. A withdrawal reflex from a painful stimulus is an example of:

A) Somatic reflex arc
B) Autonomic reflex arc
C) Visceral reflex arc
D) Neurological reflex arc

2. During a reflex arc, where is the integration of sensory and motor signals primarily occurring?

A) Spinal cord
B) Brainstem
C) Cerebral cortex
D) Peripheral nerves

3. The ganglia located near the spinal cord and involved in the sympathetic division of the autonomic nervous system are called:

A) Terminal ganglia
B) Cranial ganglia
C) Paravertebral ganglia
D) Prevertebral ganglia

4. Which of the following is NOT a typical response of the sympathetic nervous system during the fight-or-flight response?

A) Pupil dilation
B) Bronchoconstriction
C) Increased heart rate
D) Vasoconstriction of peripheral blood vessels

5. During sympathetic activation, which of the following occurs?

A) Decreased heart rate
B) Constriction of bronchioles
C) Dilation of blood vessels in skeletal muscles
D) Increased digestive activity

6. Sympathetic stimulation causes:

A) Pupil constriction
B) Decreased blood pressure
C) Increased sweating
D) Relaxation of the urinary bladder sphincter

7. Which gland is activated by sympathetic stimulation to release hormones such as epinephrine and norepinephrine?

A) Pancreas
B) Thyroid
C) Adrenal medulla
D) Pineal gland

8. A 25-year-old male is being chased by a dog. Which of the following is most likely to occur due to activation of the sympathetic nervous system?

A) Decreased heart rate
B) Bronchoconstriction
C) Increased gastrointestinal motility
D) Increased heart rate and bronchial dilation

9. A patient presents with excessive sweating (hyperhidrosis). This condition is most likely due to overactivity of which part of the autonomic nervous system?

A) Parasympathetic nervous system
B) Enteric nervous system
C) Sympathetic nervous system
D) Central nervous system

10. A 30-year-old female experiences dizziness upon standing up quickly. Which dysfunction might be responsible for her symptoms?

A) Parasympathetic insufficiency
B) Sympathetic overactivity
C) Sympathetic insufficiency
D) Increased vagal tone

11. During a stress test, which of the following changes would you expect to observe in a patient's cardiovascular system?

A) Decreased cardiac output
B) Increased cardiac output and blood pressure
C) Decreased blood pressure
D) Increased gastrointestinal blood flow

12. A patient with an adrenal tumor (pheochromocytoma) is experiencing episodic headaches, sweating, and palpitations. What hormone is likely elevated in this condition?

A) Insulin
B) Cortisol
C) Epinephrine
D) Glucagon

13. A 60-year-old male presents with ptosis, miosis, and anhidrosis on one side of his face. Which of the following conditions is most likely?

A) Bell's palsy
B) Horner's syndrome
C) Myasthenia gravis
D) Guillain-Barré syndrome

Answers:

1. A) Somatic reflex arc
2. A) Spinal cord
3. C) Paravertebral ganglia
4. B) Bronchoconstriction
5. C) Dilation of blood vessels in skeletal muscles
6. C) Increased sweating
7. C) Adrenal medulla
8. D) Increased heart rate and bronchial dilation
9. C) Sympathetic nervous system
10. C) Sympathetic insufficiency
11. B) Increased cardiac output and blood pressure
12. C) Epinephrine
13. B) Horner's syndrome

Parasympathetic Nervous System

1. Cranial outflow (Supply head, thorax, and abdomen)

Oculomotor (3rd cranial)	**Eye: Muscles:**	**Motor to all** ▪ **Constriction of pupil (miosis)** ▪ **Accommodation for near vision (increase power of lens)**
Facial (7th cranial)	1-Lacrimal gland	1- Secretory fibers stimulation 2- Vasodilatation of blood vessels → tears
	2-Nasopharyngeal glands & soft palate	1- Secretory fibers stimulation 2- Vasodilatation of blood vessels.
	3-Sublingual & submaxillary glands	1- Secretory fibers stimulation 2- Vasodilatation of blood Vessels → saliva (copious watery, rich in electrolytes)
	4- Tongue	Vasodilatation of blood of ant 2/3
Glossopharyngeal (9th cranial)	1- Parotid gland	1- secretory fibers stimulation 2- vasodilatation of blood Vessels → saliva (copious watery, rich in electrolytes)
	2- Tongue	Vasodilatation of blood vessels of post 1/3

Vagus (10th cranial)	**1- Heart** a. Heart properties b. Coronaries **2- Lung** a. Plain (smooth) muscle of the bronchi and bronchioles b. Bronchial mucous membrane **3- GIT** a. Smooth muscles and sphincters of esophagus, stomach, small intestine, proximal half of large intestine, GB (sphincter of Oddi) b. Stomach cells c. Pancreatic cells	▪ Inhibition →↓contractility of atria only, rhythmicity, excitability and conductivity ▪ Vasoconstriction → reduction of the blood supply and O2 consumption of the cardiac muscle ▪ Motor → broncho- constriction. ▪ Secretory → mucus ▪ Motor to muscle and inhibitory to sphincter ▪ Secretion → gastric juice, rich in HCL & enzymes ▪ Secretion → a. Pancreatic juice rich in enzymes b. Beta cells of islets of Langerhans → insulin

2. Sacral outflow (Supply pelvic viscera and external genital)

1- Wall & sphincter of distal half of colon and rectum	Motor to wall and inhibitory to internal anal sphincter → defecation
2- Wall & sphincter of urinary bladder	Motor to wall and inhibitory to internal urethral sphincter → micturition
3- Seminal vesicle & prostate	Secretory → semen
4- Blood vessel of erectile tissue in penis in males, vulva & clitoris in females	Vasodilatation → erection (nervous origins)

N.B: Erectile tissue of penis in males, vulva & clitoris in females are the only vascular system in pelvis that is supplied by parasympathetic.

N.B: External urethral and anal sphincters are skeletal muscles and are supplied by somatic spinal nerve called pudendal nerve.

Functions of parasympathetic system:

1. Anabolic nervous system

a. It favors digestion and absorption of food by:

- ↑ Activity of intestinal musculature
- ↑ Gastric acid secretion
- Relaxing pyloric sphincter. i.e. it is concerned with the vegetative aspects of day-to-day living

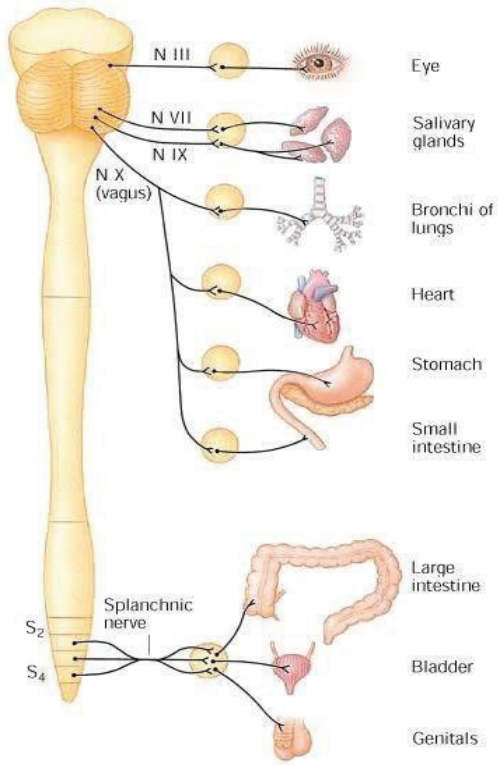
b. Prepares body for recovery and repair:

- The activity of parasympathetic is continues and even increases during rest and sleep.

N.B: sympathetic nervous system is a catabolic system.

2. localized action of parasympathetic system

- **Most functions of parasympathetic system are specific and localized:**
  - Decrease heart rate without affecting other systems.
  - Secretion may be mainly from mouth glands, in other instances secretion is mainly from stomach cells.
  - Rectal emptying reflex takes place, without affecting other parts of bowel to a major extent.
- **Paradoxical fear:** when there is no escape route or no way to win (failure of sympathetic).
  - Causes massive activation of parasympathetic division.
  - loss of control over urination and defecation.



Para-sympathetic Tone:

- **Definition:**
  - It is continuous mild parasympathetic impulses (activity) even during rest.
- **Target Tissues:**

Sino-Atrial Node (SAN, = Vagal tone on the heart):

- Leading to decrease in the intrinsic high rhythm of the heart from 120 to 70-90 during rest to preserve energy of the heart.
- So,
  - ↑Heart rate → produced by ↓ vagal tone.
  - ↓Heart rate → produced by ↑ vagal tone.

Organs with Dual Innervation

- Most visceral organs receive dual innervation
- They are innervated by both sympathetic and parasympathetic fibers. In this condition, the effects o the two divisions of the autonomic system may be antagonistic, complementary, or cooperative.

Antagonistic Effects:

- **Definition:** Antagonistic effects occur when the sympathetic and parasympathetic divisions of the autonomic nervous system have opposing effects on the same organ or system.
- One division stimulates a response, while the other inhibits it.
- **Examples:**

1. Heart:

- **Sympathetic:** Increases heart rate.
- **Parasympathetic:** Decreases heart rate.

2. Digestive Tract:

- **Sympathetic:** Inhibits intestinal motility and secretions.
- **Parasympathetic:** Stimulates intestinal motility and secretions.

- Regulation is balanced by the two effects

Complementary effects:

- **Definition:** Complementary effects occur when the sympathetic and parasympathetic divisions of the autonomic nervous system produce different effects that work together to achieve a single, coordinated action.
- **Examples:**

  Reproductive System:

  - **Sympathetic:** Induces ejaculation through vasoconstriction.
  - **Parasympathetic:** Causes erection through vasodilation.
  - **Outcome:** Both systems work together to facilitate sexual function, with each system contributing to different phases of the process.

Synergistic effects / Cooperative effects:

- **Definition:** Synergistic effects occur when the sympathetic and parasympathetic divisions of the autonomic nervous system work together in a complementary manner to produce a specific outcome, often enhancing or modifying the response.
- **Examples:**

  Salivary Glands:

  - **Sympathetic:** Constricts blood vessels, leading to thicker, more viscous saliva.
  - **Parasympathetic:** Stimulates the production of watery saliva.
  - **Outcome:** The combined action results in saliva with different properties based on the balance of sympathetic and parasympathetic inputs.

Organs Without Dual Innervation:

Only sympathetic innervation:	Only parasympathetic innervation:
▪ Sweat glands. ▪ Piloerector muscle. ▪ Blood vessels all over the body except the penis. ▪ Capsule of the spleen ▪ Dilator pupillae muscle. ▪ Blood vessels of the skeletal muscles. ▪ Adrenal medulla	▪ The lacrimal gland. ▪ Ciliary muscle (for accommodation for near vision) ▪ The nasopharyngeal gland.

N.B: In these cases, regulation is achieved by increases or decreases in the tone (**firing rate**) of the sympathetic fibers. For example, constriction of cutaneous blood vessels is produced by increased sympathetic activity that stimulates alpha- adrenergic receptors, and vasodilation results from decreased sympathetic nerve stimulation.

Comparison between sympathetic and parasympathetic

	Sympathetic	Parasympathetic
Origin	Thoraco-lumbar outflow (T1 – L2)	Craniosacral outflow III, VII, IX, X, S2,3,4
Preganglionic	▪ Short, from spial cord to sympathetic chain. ▪ Synapse .. activates many postganglionic fibers	▪ Long, from brain or spinal cord to terminal ganglia. ▪ Synapse .. activates few postganglionic fibers
Ganglia	Lateral (paravertebral) Collateral (prevertebral)	Terminal
Postganglionic	Long, from sympathetic chain to the effector organ	Short, because ganglia are embedded in effector organ
Functionaly	▪ Catabolic ▪ Prepare the body for vigorous muscle activity (fight or flight) ▪ Action is widespread	▪ Anabolic ▪ Concerned with vegetative aspects of day-to-day living. ▪ Action is localized and discrete
Chemical transmitter	Mainly nor-adrenaline	Acetylcholine
Effect on Heart Rate	Increases heart rate	Decreases heart rate
Effect on Airway Diameter	Dilates airways Bronchodilation	Constricts airways (bronchoconstriction)
Effect on Pupil Size	Dilates pupils (mydriasis)	Constricts pupils (miosis)
Effect on Digestion	Inhibits digestion (decreased peristalsis, reduced glandular secretions)	Stimulates digestion (increased peristalsis, enhanced glandular secretions
Effect on Salivation	Viscid saliva	Increases salivation
Effect on Bladder	Relaxes bladder wall (promotes urine retention)	Contracts bladder wall (promotes urination)
Effect on Blood Flow	Redistributes blood flow to skeletal muscles and heart	Redistributes blood flow to digestive organs and skin
Function During Rest	Active but less dominant	Dominant (promotes rest, recovery, and digestion)

Test yourself!

1. Which cranial nerve carries parasympathetic fibers to the lacrimal gland for tear secretion?

A) Trigeminal (V)
B) Facial (VII)
C) Glossopharyngeal (IX)
D) Vagus (X)

2. Which gland receives parasympathetic innervation via the glossopharyngeal nerve (IX)?

A) Parotid gland
B) Sublingual gland
C) Lacrimal gland
D) Submandibular gland

3. Parasympathetic fibers from which cranial nerve contribute to the innervation of the stomach and proximal half of the large intestine?

A) Facial (VII)
B) Glossopharyngeal (IX)
C) Vagus (X)
D) Accessory (XI)

4. Which function is primarily associated with parasympathetic activity in the gastrointestinal tract?

A) Inhibits gastric acid secretion
B) Inhibits peristalsis
C) Constricts pyloric sphincter
D) Stimulates intestinal motility

5. What effect does parasympathetic stimulation have on the ciliary muscle of the eye?

A) Contraction
B) Relaxation
C) No effect
D) Induces mydriasis

6. Which of the following statements about parasympathetic nervous system function is true?

A) It is involved in the "fight-or-flight" response
B) It releases adrenaline from the adrenal medulla
C) It promotes energy mobilization
D) It promotes rest, digestion, and recovery

7. Which cranial nerve carries parasympathetic fibers that innervate the heart, lungs, and gastrointestinal tract?

A) Trigeminal (V)
B) Vagus (X)
C) Hypoglossal (XII)
D) Oculomotor (III)

8. Parasympathetic stimulation of the salivary glands primarily leads to:

A) Decreased saliva production
B) Thick, viscous saliva secretion
C) Inhibition of salivation
D) Watery, electrolyte-rich saliva secretion

9. Parasympathetic innervation of the penis primarily leads to:

A) Erection
B) Ejaculation
C) Contraction of the bulbospongiosus muscle
D) Constriction of penile blood vessels

10. Which of the following organs receives parasympathetic innervation via the oculomotor nerve (III)?

A) Lacrimal gland
B) Ciliary muscle
C) Submandibular gland
D) Parotid gland

11. Which of the following is NOT a function associated with parasympathetic activity?

A) Constriction of bronchioles
B) Stimulation of salivary gland secretion
C) Constriction of pupils
D) Stimulation of peristalsis in the digestive tract

12. A 50-year-old woman is undergoing a medical examination and exhibits a relaxed demeanor, slow heart rate, and constricted pupils. Based on these observations, Which autonomic nervous system division is most active in promoting relaxation, decreased heart rate, and constricted pupils?

A) Sympathetic nervous system
B) Parasympathetic nervous system
C) Both sympathetic and parasympathetic nervous systems
D) Neither division

13. A 40-year-old man is experiencing frequent urination and has a high bladder tone. These symptoms suggest increased activity of which autonomic nervous system division?
Which division of the autonomic nervous system is responsible for increasing bladder tone and contractions?

A) Sympathetic nervous system
B) Parasympathetic nervous system
C) Both sympathetic and parasympathetic nervous systems
D) Neither division

14. A patient is undergoing a stress test and reports dry mouth and difficulty swallowing. These symptoms are likely due to reduced activity of which autonomic nervous system division?
Which division of the autonomic nervous system, when underactive, is most likely responsible for dry mouth and difficulty swallowing?

- A) Sympathetic nervous system
- B) Parasympathetic nervous system
- C) Both sympathetic and parasympathetic nervous systems
- D) Neither division

15. A 55-year-old man is prescribed a medication that enhances parasympathetic activity. What effect would this medication most likely have on his heart rate? What is the expected effect on heart rate from medication that enhances parasympathetic activity?

A) Increase heart rate
B) Decrease heart rate
C) No effect on heart rate
D) Increase and then decrease heart rate

16. A patient with hypertension presents with dilated pupils and an elevated heart rate. Which autonomic nervous system division is likely less active in this case? Which autonomic nervous system division is likely less active if a patient has dilated pupils and an elevated heart rate?

A) Sympathetic nervous system
B) Parasympathetic nervous system
C) Both sympathetic and parasympathetic nervous systems
D) Neither division

17. A 30-year-old man is found to have high peristalsis and increased salivation during a relaxation therapy session. Which division of the autonomic nervous system is primarily responsible for these effects? Which division of the autonomic nervous system is primarily responsible for increased peristalsis and salivation during a relaxation session?

A) Sympathetic nervous system
B) Parasympathetic nervous system
C) Both sympathetic and parasympathetic nervous systems
D) Neither division

18. A patient is diagnosed with difficulty in digestion and constipation. Which autonomic dysfunction is most likely affecting the gastrointestinal system? What type of autonomic dysfunction is most likely responsible for difficulty in digestion and constipation?

A) Increased sympathetic activity
B) Decreased parasympathetic activity
C) Increased parasympathetic activity
D) Decreased sympathetic activity

Answers:

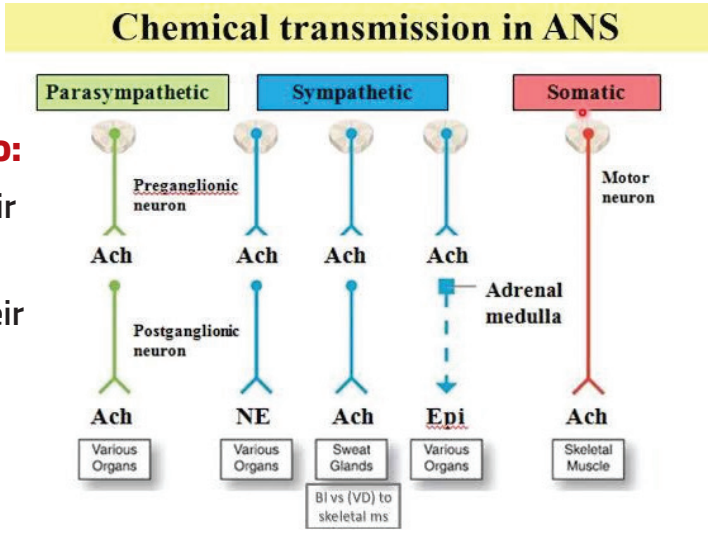
1. B) Facial (VII)
2. A) Parotid gland
3. C) Vagus (X)
4. D) Stimulates intestinal motility
5. A) Contraction
6. D) It promotes rest, digestion, and recovery
7. B) Vagus (X)
8. D) Watery, electrolyte-rich saliva secretion
9. A) Erection
10. B) Ciliary muscle
11. A) Constriction of bronchioles
12. B) Parasympathetic nervous system
13. B) Parasympathetic nervous system
14. B) Parasympathetic nervous system
15. B) Decrease heart rate
16. B) Parasympathetic nervous system
17. B) Parasympathetic nervous system
18. B) Decreased parasympathetic activity

Chemical Transmission

- **Definition:**
  - **Transmission of nerve impulse by releasing chemical substance at:**
    1. Autonomic ganglia between preganglionic and postganglionic neurons
    2. Between postganglionic neurons and the autonomic effectors
    3. Somatic neuromuscular transmission is also chemically transmitted by acetylcholine that depolarizes the end plate.

- **Principle autonomic chemical transmitters:**
  1. Acetylcholine
  2. Norepinephrine (noradrenaline)

- **The autonomic fibers are classified into:**
  1. **Cholinergic:** secreting acetylcholine at their terminals.
  2. **Adrenergic:** secreting noradrenaline at their terminals



1. Cholinergic transmission:

Acetylcholine & cholinergic fibers:

a- Autonomic NS

- **At Preganglionic fibers of:**
  1. All sympathetic and parasympathetic preganglionic neurons i.e. all autonomic ganglia
  2. Adrenal medulla
- **At Postganglionic fibers of:**
  1. All parasympathetic postganglionic neurons
  2. **Sympathetic postganglionic nerve endings of:**
     a. Sweat glands
     b. Blood vessels in the skeletal muscles.

b- Somatic system

- **Somatic motor nerve fibers to the skeletal muscle (myoneural junction).**

N.B: All Central fibers are Cholinergic

Acetyl choline receptors : There are two different types of receptors; muscarinic and nicotinic.

	Muscarinic Receptors	Nicotinic Receptors
Activation	Activated by muscarine and acetylcholine.	Activated by small doses of nicotine and acetylcholine.
Effect	Can be excitatory or inhibitory.	Always excitatory.
Locations	1. All effector cells supplied by parasympathetic postganglionic neurons 2. On the surface of: a. Sweat glands b. Blood vessels in the skeletal muscles.	1. The synapses between the pre-and postganglionic neurons of both the sympathetic and parasympathetic systems. 2. In the membranes of skeletal muscle fibers at the neuromuscular junction. 3. Suprarenal medulla.
Action of acetylcholine:	**Actions produced by stimulation of the muscarinic receptors:** ▪ Because both acetylcholine and muscarine have similar effects on muscarinic receptors, these actions are described as muscarine like actions of acetylcholine. Stimulation of: a. All postganglionic parasympathetic endings b. Sympathetic postganglionic endings to sweat glands and skeletal blood vessels	**Actions produced by stimulation of the nicotinic receptors:** ▪ Because both acetylcholine and nicotine have similar effects on the nicotinic receptors, so these actions are described as nicotine-like actions of acetylcholine. a. Stimulation of the autonomic ganglia. b. Secretion of adrenaline and noradrenaline at adrenal medulla. c. Contraction of skeletal muscles due to stimulation at the motor end plates.

N.B: Atropine:

Medication work s by blocking muscarinic acetylcholine receptors (blocking the action of acetylcholine at parasympathetic nerve endings thus inverse the effects)

So can used to

1. Increased Heart Rate (positive chronotropic effect).
2. Decreased Salivation.
3. Relaxation of Smooth Muscle.
4. Mydriasis: Atropine causes dilation of the pupils.
5. Reduce respiratory secretions and bronchoconstriction.

2. Sympathetic transmission:

Catecholamines: Noradrenaline (Norepinephrine), Adrenalin (Epinephrine):

1. All sympathetic postganglionic nerve endings except:
   a. Sweat glands
   b. Blood vessels in the skeletal muscles.
2. Adrenal medulla

Adrenergic receptors:

	Alpha 1	Alpha 2	Beta 1	Beta 2
Location	On effector cells	Presynaptic nerve terminals	Chiefly on the heart	Smooth muscles of bronchioles, GIT, and urinary bladder
Primary Neurotransmitter	Noradrenaline		Adrenaline	
Affinity	Higher affinity to noradrenaline		Higher affinity to adrenaline	
Effect	Mainly excitatory	Inhibitory	Excitatory	Inhibitory
Specific Actions	Vasoconstriction, spleen contraction, erection of hair	Prevents excessive or prolonged noradrenaline release	Increases heart rate, muscle contraction	Relaxes smooth muscle in bronchioles, GIT, and urinary bladder

In alpha 1 receptors : there are exceptions e.g. they are inhibitory to intestinal TL muscles (relaxation).

Action of Noradrenaline and adrenaline:

- **Noradrenaline:**
  1. Excite mainly alpha-receptors but excites the beta-receptors to slight extent as well.
  2. Thus noradrenaline released by the sympathetic adrenergic nerve endings is responsible for various sympathetic effects.
  3. Noradrenaline secreted by the adrenal medulla has the same effects on the different organs, except that its action lasts for longer time because it is slowly removed from the blood.
- **Adrenaline:**
  - Excites both types of receptors approximately equally.

Differences between Noradrenaline and adrenaline:

- Adrenaline causes almost the same effects as those caused by noradrenaline, but the effects differ in the following respects:

	Adrenaline (Epinephrine)	Noradrenaline (Norepinephrine)
Source	Adrenal medulla	Adrenal medulla and sympathetic nerve endings
Primary Receptors	Alpha and Beta receptors	Mainly Alpha receptors
Blood vessels	Weak VC	Strong VC
Cardiac stimulation	More	Less
Smooth muscles of bronchioles & intestine	More inhibitory effect	Less inhibitory effect
Metabolic effect	More	Less
Main Effects	▪ Increases heart rate ▪ Increases blood pressure ▪ Bronchodilation ▪ Increases blood glucose levels	▪ Increases blood pressure ▪ Vasoconstriction ▪ Decreases intestinal motility
Clinical Uses	▪ Cardiac arrest ▪ Asthma	▪ Hypotension

Value and role of the adrenal medulla to the function of the sympathetic NS:

- **Organs are stimulated in two different ways simultaneously:**
  1. Directly by sympathetic nerves.
  2. Indirectly by the medullary hormones.
- These two means of stimulation support each other and can usually substitute each other.
- Total loss of the two adrenal medulla has a little effect on sympathetic nervous system because the direct pathways still can perform all the necessary duties.

Control Of Autonomic Functions

I- Spinal cord: Simple autonomic reflexes such as (micturition and defection)

II- Brain stem Medulla, pons and midbrain control different autonomic functions such as blood pressure and heart rate

III- Higher control: (i.e., above brain stem):

- The autonomic centers in the lower brain stem acts as relay stations for control activities initiated at higher levels of the brain.

1. Hypothalamus:

a. Stimulation of anterior hypothalamic nuclei parasympathetic response

b. Stimulation of posterior hypothalamic nuclei sympathetic response

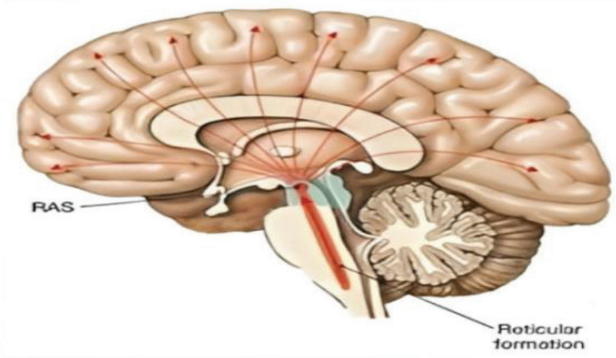
2. Cerebral cortex:

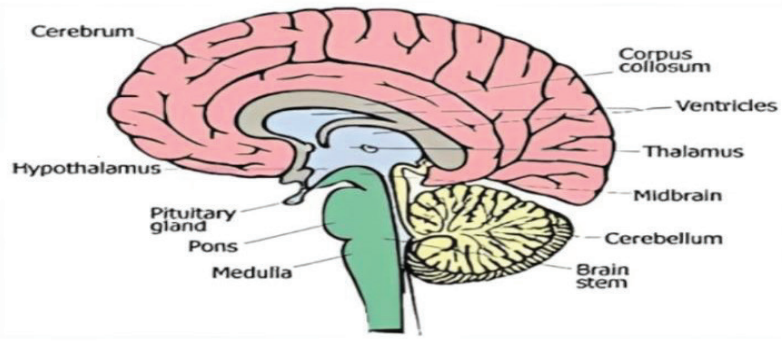
- affects both sympathetic and parasympathetic functions.

3. Reticular formation:

- Responsible for the tone of sympathetic and parasympathetic (i.e., normal functions during basal rate of activity).

The higher areas of the brain can alter functions of the whole autonomic nervous system or portion of it, strongly enough to cause severe autonomic induced disease such as: peptic ulcer, constipation or diarrhea,





Test yourself!

1. Which neurotransmitter is released by all preganglionic autonomic neurons?*

A) Dopamine
B) Serotonin
C) Acetylcholine
D) Norepinephrine

2. Which of the following is NOT a location where acetylcholine acts in the autonomic nervous system?

A) Sympathetic preganglionic neurons
B) Parasympathetic postganglionic neurons
C) Sympathetic postganglionic neurons to sweat glands
D) Blood vessels of skeletal muscles

3. What type of receptors do sweat glands have for acetylcholine?

A) Nicotinic receptors
B) Muscarinic receptors
C) Alpha receptors
D) Beta receptors

4. Which of the following receptors are primarily activated by small doses of nicotine?

A) Muscarinic receptors
B) Alpha receptors
C) Nicotinic receptors
D) Beta receptors

5. What is the effect of acetylcholine on muscarinic receptors?

A) Always excitatory
B) Always inhibitory
C) Can be either excitatory or inhibitory
D) None of the above

6. Which of the following is an action produced by stimulation of nicotinic receptors?

A) Secretion of adrenaline and noradrenaline at the adrenal medulla
B) Inhibition of sweat glands
C) Vasodilation of blood vessels in skeletal muscles
D) Decrease in heart rate

7. Which neurotransmitter is primarily responsible for vasoconstriction in blood vessels?

A) Acetylcholine
B) Noradrenaline
C) Dopamine
D) Serotonin

8. Which of the following is NOT a characteristic effect of noradrenaline?

A) Strong vasoconstriction

B) More cardiac stimulation compared to adrenaline

C) Mainly excites alpha receptors

D) Inhibitory effect on smooth muscles of the intestines

9. Which of the following effects is more prominent with adrenaline compared to noradrenaline?

A) Weak vasoconstriction

B) Stronger metabolic effect

C) Less inhibitory effect on bronchioles

D) Less cardiac stimulation

10. Which of the following statements about the adrenal medulla is correct?

A) It secretes only noradrenaline.

B) It has no significant effect on the sympathetic nervous system.

C) Its hormones can substitute the direct sympathetic pathways.

D) Its total loss severely impairs sympathetic functions.

11. A patient is administered a norepinephrine drip. Which of the following are likely side effects?

A) Tachycardia

B) Hypoglycemia

C) Hypotension

D) Bronchoconstriction

Answers:

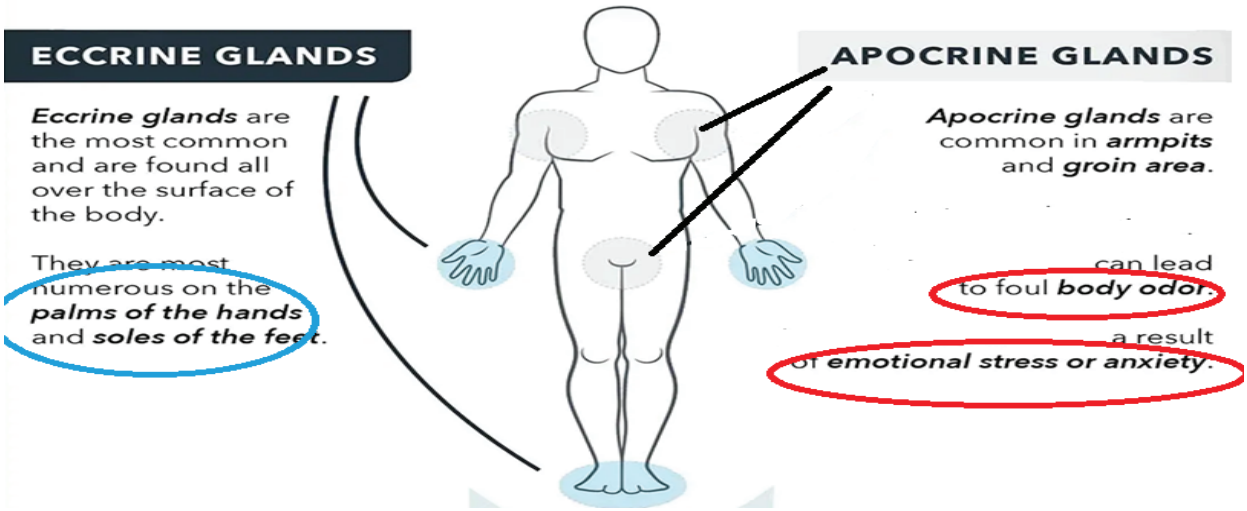
1. C - Acetylcholine
2. D - Blood vessels of skeletal muscles
3. B - Muscarinic receptors
4. C - Nicotinic receptors
5. C - Can be either excitatory or inhibitory
6. A - Secretion of adrenaline and noradrenaline at the adrenal medulla
7. B - Noradrenaline
8. B - More cardiac stimulation compared to adrenaline
9. B - Stronger metabolic effect
10. C - Its hormones can substitute the direct sympathetic pathways
11. A) Tachycardia

Practical physiology

Sweating occurs upon exposure to stressors

- Sweating is under control of the sympathetic nervous system.
- **There are 2 main types of glands that respond to sympathetic stimulation in the skin :**
  A) Eccrine sweat glands
  B) Apocrine glands

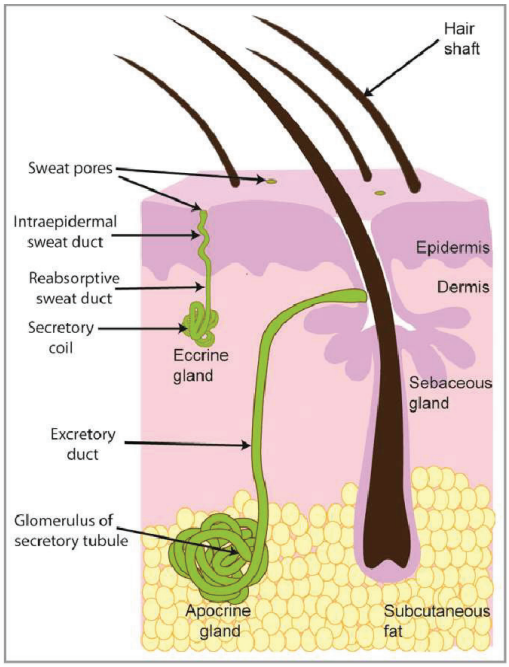
Skin glands under sympathetic control



Glands in the skin

a) Eccrine sweat glands

- Present all over the body , in palms and sole of feet.
- Open directly on the skin surface.
- Start to function soon after birth.
- Secrete sweat , help in thermoregulation.
- Supplied by sympathetic cholinergic fibers.



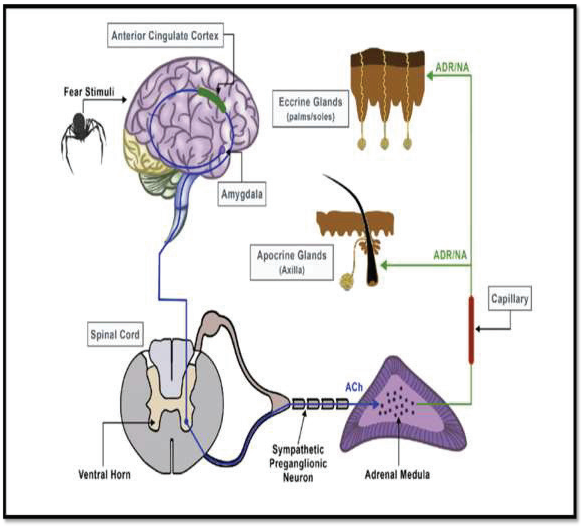
b) Apocrine glands

- Present in hairy skin as in the axilla and inguinal areas.
- Open into hair follicles.
- Start to function at puberty.
- Secrete an oily substance and pheromones (human scent glands).
- Emotional sweating.
- Supplied by sympathetic adrenergic fibers.

Cascade of actions

Arousal (from sympathetic stimulation) → Sweating → Decreased resistance of the skin to transmit electrical current

- Conductance = 1 /resistance
- **Changes in the skin conductance** are used as an indicator of physiological or psychological arousal or stress due to fight or flight response)



Electrodermal activity (EDA)

- **Definition :**
  - These are electrical changes, measured at the surface of the skin, that arise when the skin receives innervating signals from the brain.
  - i.e. the skin momentarily becomes a better conductor of electricity when external or internal stimuli cause physiological arousal.
  - It reflects the activity of the sympathetic nervous system on sweat glands.
  - Because sweating increases skin conductance (conductance = 1/resistance).
  - It is expressed in conductance units (as microsiemens)

2 components of electrodermal skin activity

- **Tonic skin conduction level**
  - Base line skin conductance waves
  - Specific to individual
- **Phasic skin conductance response**
  - Occur in response to stimuli
  - rapidly changing peaks
- Due to activation of sudomotor fibers (to sweat glands)

Which components are used as a strong markers of the sympathetic activity?

1) Skin conductance response (SCR)

- It is usually expressed in conductance units (as microsiemens) (conductance = 1/resistance).
- On the computer screen , we see : changes in waves amplitude, and time related indices as response latency (how much time taken to start a wave)

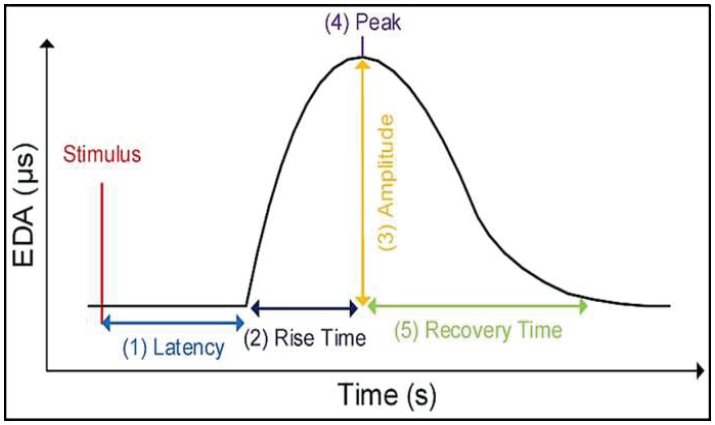
2) Changes in heart rate

- In response to stressors (also recorded during the experiment) With or without

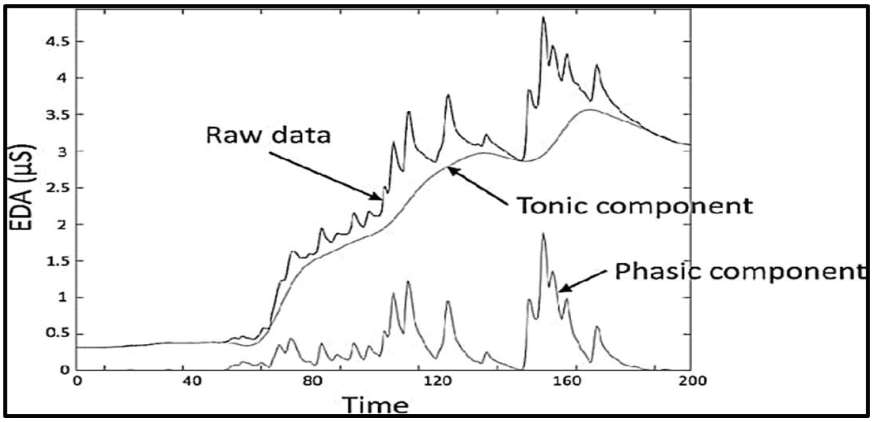
3) Changes in breathing pattern

- **In skin conductance response , five factors may change in any wave:**

1. Latency.
2. Rise time.
3. Amplitude.
4. Peak.
5. Recovery time.



- **Tonic skin conduction versus phasic skin conductance response**



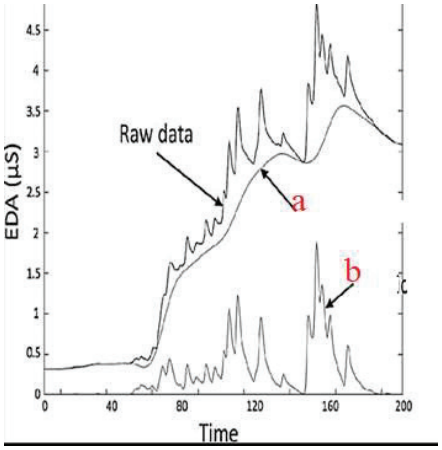
- **Tonic skin conductance versus phasic skin conductance response**

Tonic (a)

- Base line skin conductance waves
- Specific to individual

Phasic (b)

- Occur in response to stimuli
- Rapidly changing peaks
- Due to activation of sudomotor fibers(to sweat glands)



Experiment steps simplified

A. Proper connection

- Hardware and electrodes are connected to Biopack apparatus .

- Choose the properchannels :
- Respiratory
- Transducer CH 1
- Pulse Transducer CH 2
- EDA transducer CH 3apparatus

B. Attachment of sensors

- **Wearing proper sensors : of skin electrical activity on the left hand** and that of heart rate on the index of the right hand.

- In case of measuring changes of respiratory rate, attach the Respiratory Transducer around the Subject's chest.

C. Calibration

Three seconds after calibration begins

- Recording basal electrodermal activity (without exposure to stressors).
- Subject will inhale once quickly and deeply, and then return to normal breathing.

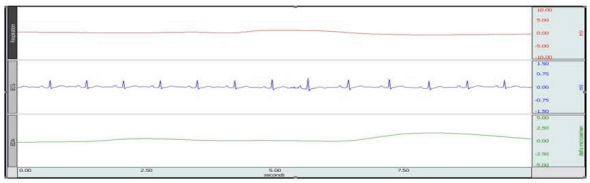


Fig. 9.11 Example Calibration data

D . Data recording

Data will be recorded during exposure of the subject to :

Different stressors (with a pause between them):

a. Questions to which the person replies by yes or no
b. Mental calculations (count down from 100 by submitting 9....)
c. Exposure to different colored cards (to detect their psychogenic effects)

Stressor 1 : Yes / No questions

Questions:

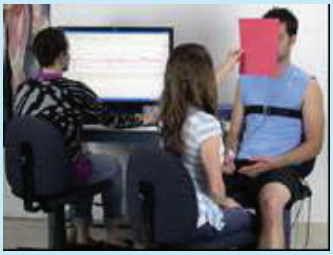
a.	Are you currently a student?	Y	N
b.	Are your eyes blue?	Y	N
c.	Do you have any brothers?	Y	N
d.	Did you earn an "A" on the last physiology exam?	Y	N
e.	Do you drive a motorcycle?	Y	N
f.	Are you less than 25 years of age?	Y	N
g.	Have you ever traveled to another planet?	Y	N
h.	Have aliens from another planet visited you?	Y	N
i.	Do you watch "Survivor?"	Y	N
j.	Have you answered all of the preceding questions truthfully?	Y	N

Stressor 2 : Count and touch

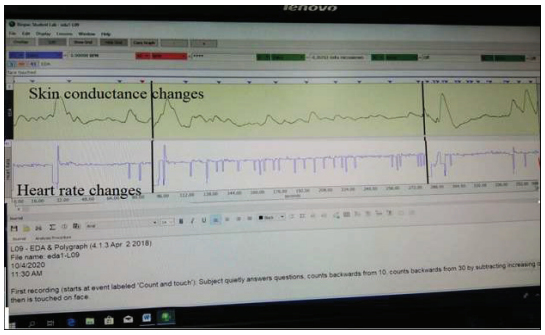
- Click **Record.**
- Five seconds into recording, **Director** asks **Subject** to say full name.
- **Recorder** presses **F2** and waits five seconds.
- **Director** asks **Subject** to count backwards from 10.
- **Recorder** presses **F3** and waits five seconds.
- **Director** asks **Subject** to count backwards from 30 by subtracting increasing odd numbers: (30, 29, 26, 21, etc.)
- **Recorder** presses **F4** and waits five seconds.
- **Director** touches **Subject** on side of face.
- **0. Recorder** presses **F5** and waits five seconds.

Stressor 3 : Exposure to colored squares

- **Director** arranges colored paper in specified sequence.
  - Subject faces **Director.**
  - Recorder prepares to insert event markers at color changes.
  - **Carefully review** upcoming steps.
- Click **Record.**
- Director holds colored paper in front of Subject.
- **Director** instructs **Subject** to concentrate each colored square for about 10 seconds, and then lowers paper for five seconds before presenting next color.
- **Recorder** inserts an event marker (F9 key) each time paper color is changed.
- Click **Suspend.**



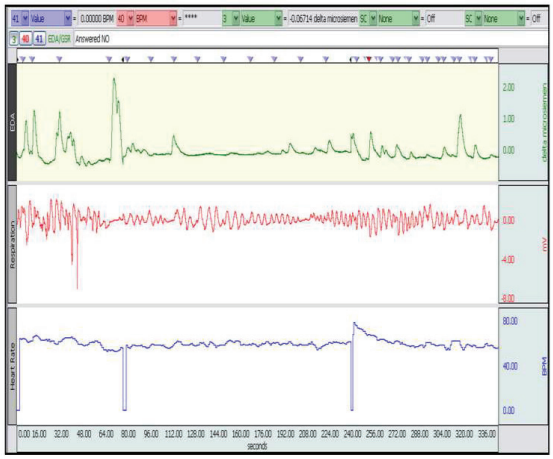
- The apparatus records different heart rate changes and changes in conductance of the skin due to stressful sweating.



In order to get correct results: The subject

- Must be relaxed, still, and facing away from monitor
- Should be at his/her resting heart rate and should not have performed any recent physical or mental exertion
- Should answer questions quietly, with minimal movement of the mouth
- AND
- The environment must be quiet, and unrelated sensory input kept at a minimum

E. Data analysis



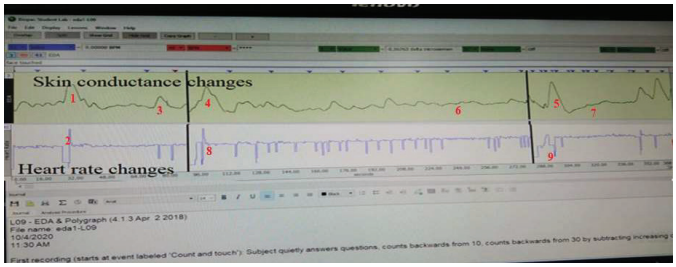
- Channel Displays
- CH 3 : electrodermal skin conductance
- CH 1 : Respiration
- CH 2: Heart Rate

Find an area of the record to analyze

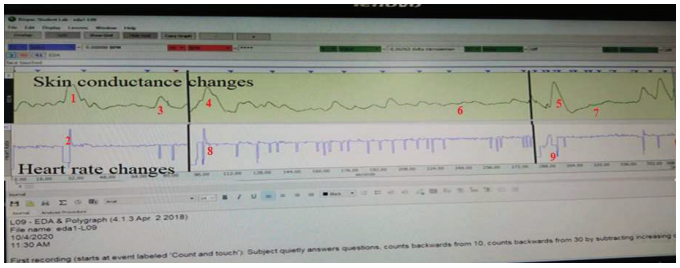
- **Select an area of the recording showing significant changes in:**
  a. The heart rate
  b. Electrodermal skin response
  c. Respiratory rate

- **Points 1, 4 and 5** indicate increased skin conductance = severe stimulation of the sympathetic nervous system as during lying or emotions
- **Point 3** shows increased skin conductance but less than at point 4 = stimulation of the sympathetic nervous system but less than at point 4

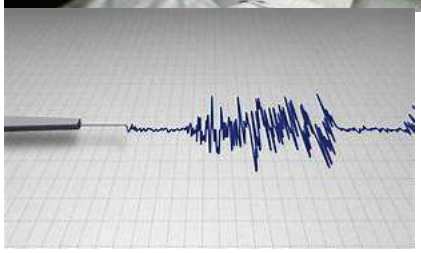
- **Point 6 and 7** indicates basic skin conduction = the sympathetic nervous system activity is not increased (as during telling the truth or relaxation.



- **Point 2 , 8 and 9** indicate increased in heart rate = sympathetic stimulation
- They occur at the same time as increased skin conduction, which clearly indicates the activity of the sympathetic nervous system is increased at these times.



- More sophisticated machines, operating by the same principle are used as **"Lie detectors"**
- The recorded curves are named **polygraph**

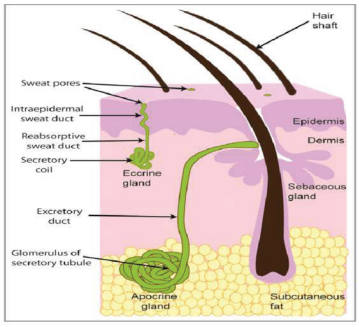


Uses of skin electrical conductance testing:

- It is one of the most sensitive measures of mental activity.
  1. Lie detectors
  2. Objective assessment of pain or distress (anaesthesia and critical care)
  3. Potential diagnosis and prediction of major depression

Practice

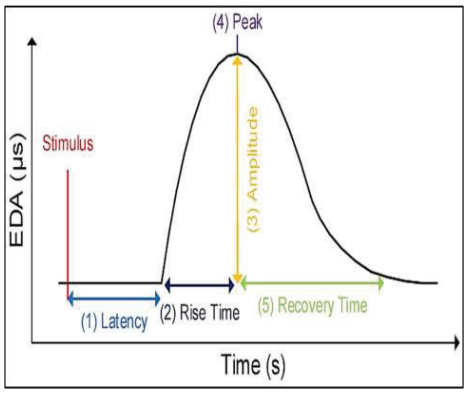
1) In electrodermal skin conductance , which glands are responsible for increased sweat secretion?



a) Eccrine glands
b) Apocrine glands
c) Sebaceous glands

Answer: eccrine

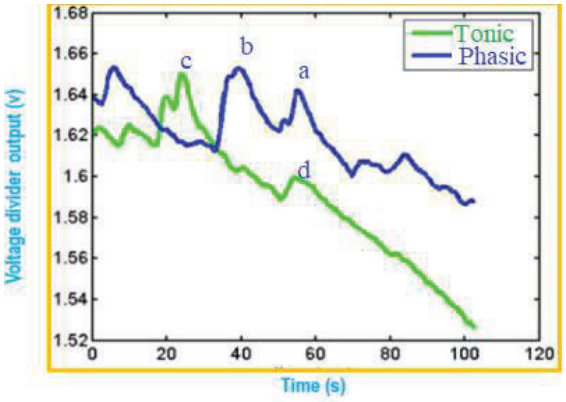
2) The higher the psychogenic response, the higher value of which elements in this wave of electrodermal skin conductance? (many answers are correct)



a) latency
b) Rise time
c) Recovery time
d) Amplitude
e) Peak

Answer: amplitude, peak , recovery time

3) In this recording of electrodermal skin activity, which letter refers to maximal tonic electrodermal skin conduction ?



a)
b)
c)
d)
e)

Answer : c

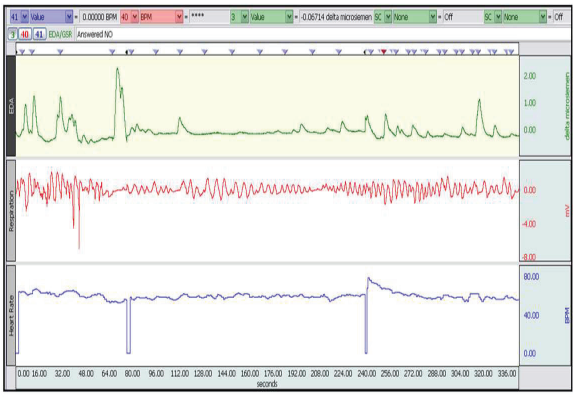
4) In electrodermal skin conductance, the red sensor in the left hand detects which of the following?

a) Electrodermal skin conductance
b) Heart rate
c) Blood pressure
d) Respiratory rate

Answer : Electrodermal skin conductance

5) In this recording of electrodermal skin conductance, which tracing belongs to changes in heart rate?

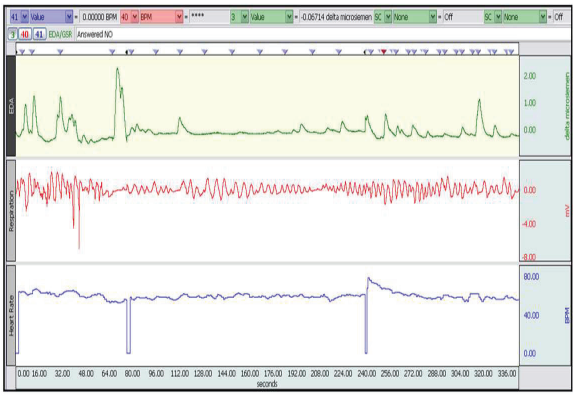
a) Red (Channel 1)
b) Blue (Channel 2)
c) Green (channel 3)



Answer: blue

6) Which units are used to measure electrodermal skin conductance?

a) Millivolts
b) Breath /min
c) MEq /l
d) Microsiemens



Answer: Microsiemens.

7) This patient was asked a question, at which point was the subject telling the truth?

a) 1
b) 3
c) 4
d) 6

Answer: 6

8) Give examples of questions that lead to phasic response of electrodermal skin activity.

Questions:

a.	Are you currently a student?	Y	N
b.	Are your eyes blue?	Y	N
c.	Do you have any brothers?	Y	N
d.	Did you earn an "A" on the last physiology exam?	Y	N
e.	Do you drive a motorcycle?	Y	N
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j.	Have you answered all of the preceding questions truthfully?	Y	N

9) Tabulate the differences between eccrine and apocrine glands

a) Eccrine sweat glands

- Present all over the body , in palms and sole of feet.
- Open directly on the skin surface.
- Start to function soon after birth.
- Secrete sweat , help in thermoregulation.
- Supplied by sympathetic cholinergic fibers.

b) Apocrine glands

- Present in hairy skin as in the axilla and inguinal areas.
- Open into hair follicles.
- Start to function at puberty.
- Secrete an oily substance and pheromones (human scent glands).
- Emotional sweating.
- Supplied by sympathetic adrenergic fibers.

10) Tabulate the differences between tonic and phasic electrodermal skin conduction

Tonic	Phasic
Base line skin conductance waves	Occur in response to stimuli
Specific to individual rapidly changing	Rapidly changing peaks
	Due to activation of sudomotor fibers (to sweat glands)

11) Explain the mechanism of electrodermal skin conduction

12) List stressors to which the subject is exposed in electrodermal skin conduction

a) Questions to which the person replies by yes or no (are you a student, do you drive a motor cycle, did you see an alien .....)

b) Mental calculations (count down from 100 by submitting 9....)

c) Exposure to different colored cards (to detect their psychogenic effects)

13) What are the manifestations of increased activity of the sympathetic nervous system measured in this experiment?

1) Changes in skin conductance (Skin conductance response) usually expressed microsiemens

2) Changes in heart rate

3) Changes in breathing pattern