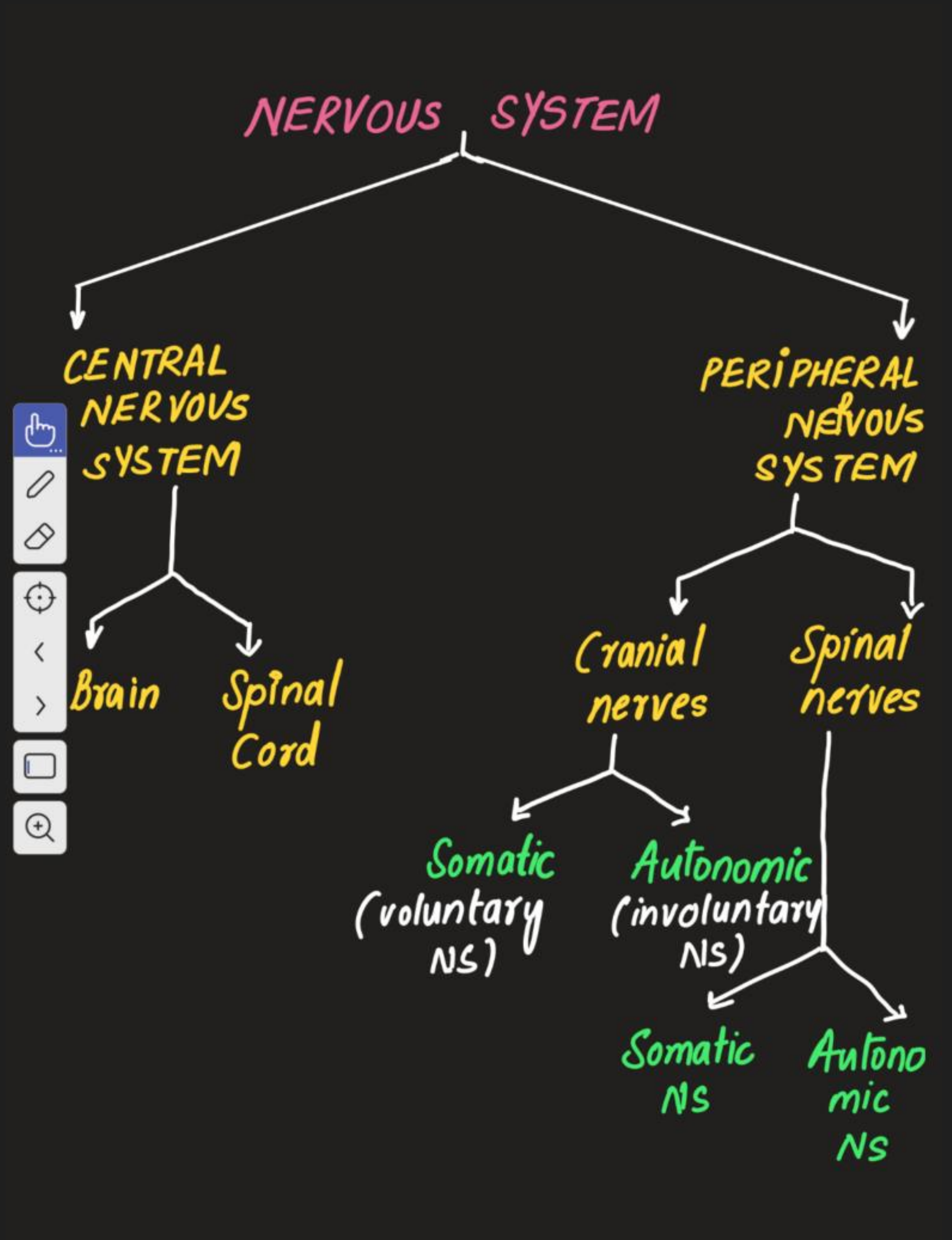
Control & Coordination



With
Mohammad Hussham Arshad, MD

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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Classification of the nervous system
- Structure of a typical motor neurone, sensory neurone & relay neurone
- Functions of the different parts of a neurone

Video Lecture 1 Slides

Mohammad Hussham Arshad, MD
Biology Department

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CONTROL AND COORDINATION

Ⓐ Nervous System

Ⓑ Female Reproductive System

Ⓒ Musculoskeletal System

Ⓓ PGRs → Gibberellins
→ Auxins

Ⓔ Electrical co-ordination in plants
→ Venus fly trap

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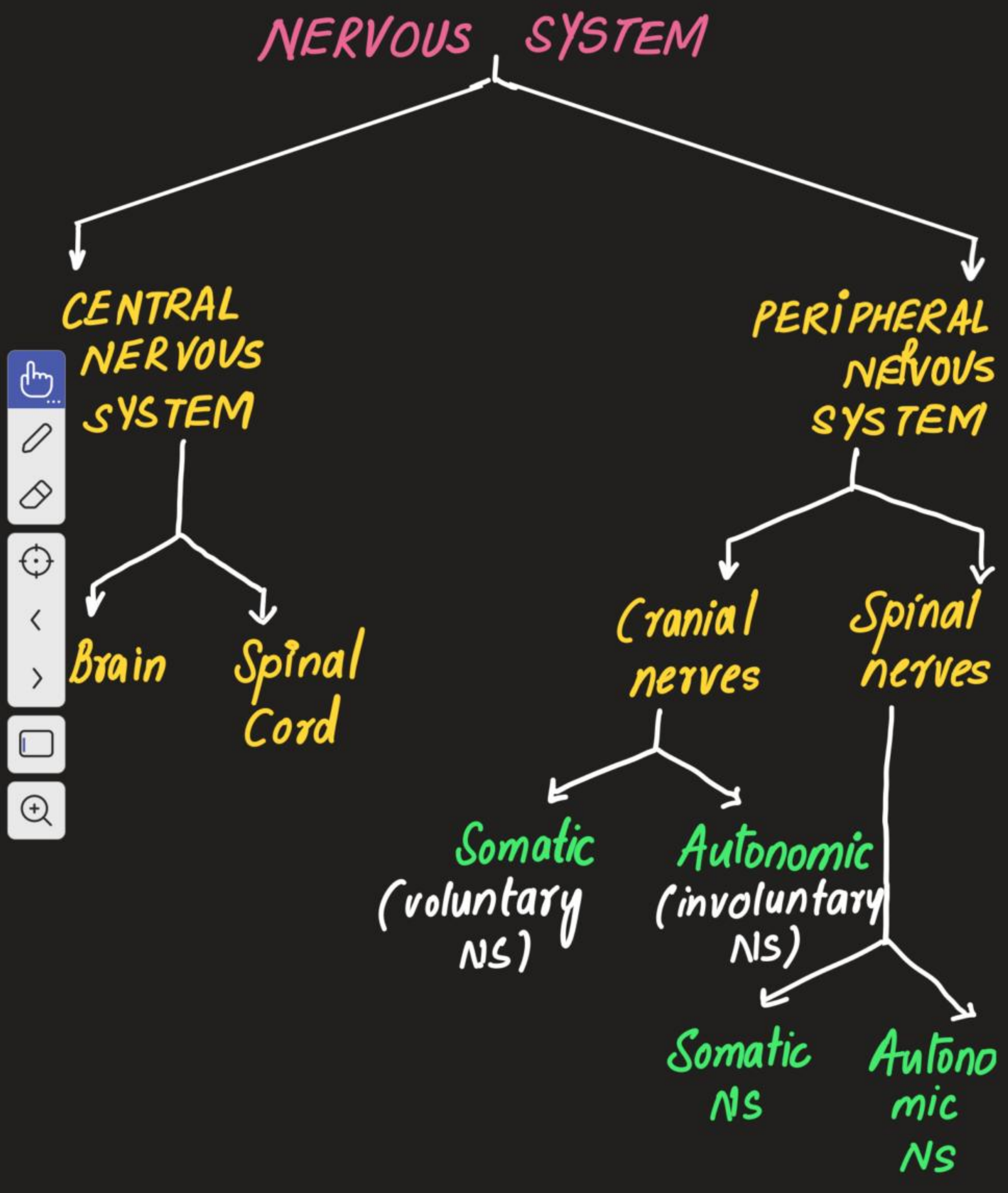
NERVOUS SYSTEM
CENTRAL NERVOUS SYSTEM
PERIPHERAL NERVOUS SYSTEM
Brain
Spinal Cord
Cranial nerves
Spinal nerves
Somatic (voluntary NS)
Autonomic (involuntary NS)
Somatic NS
Autonomic NS

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Neurones → basic unit of nervous system

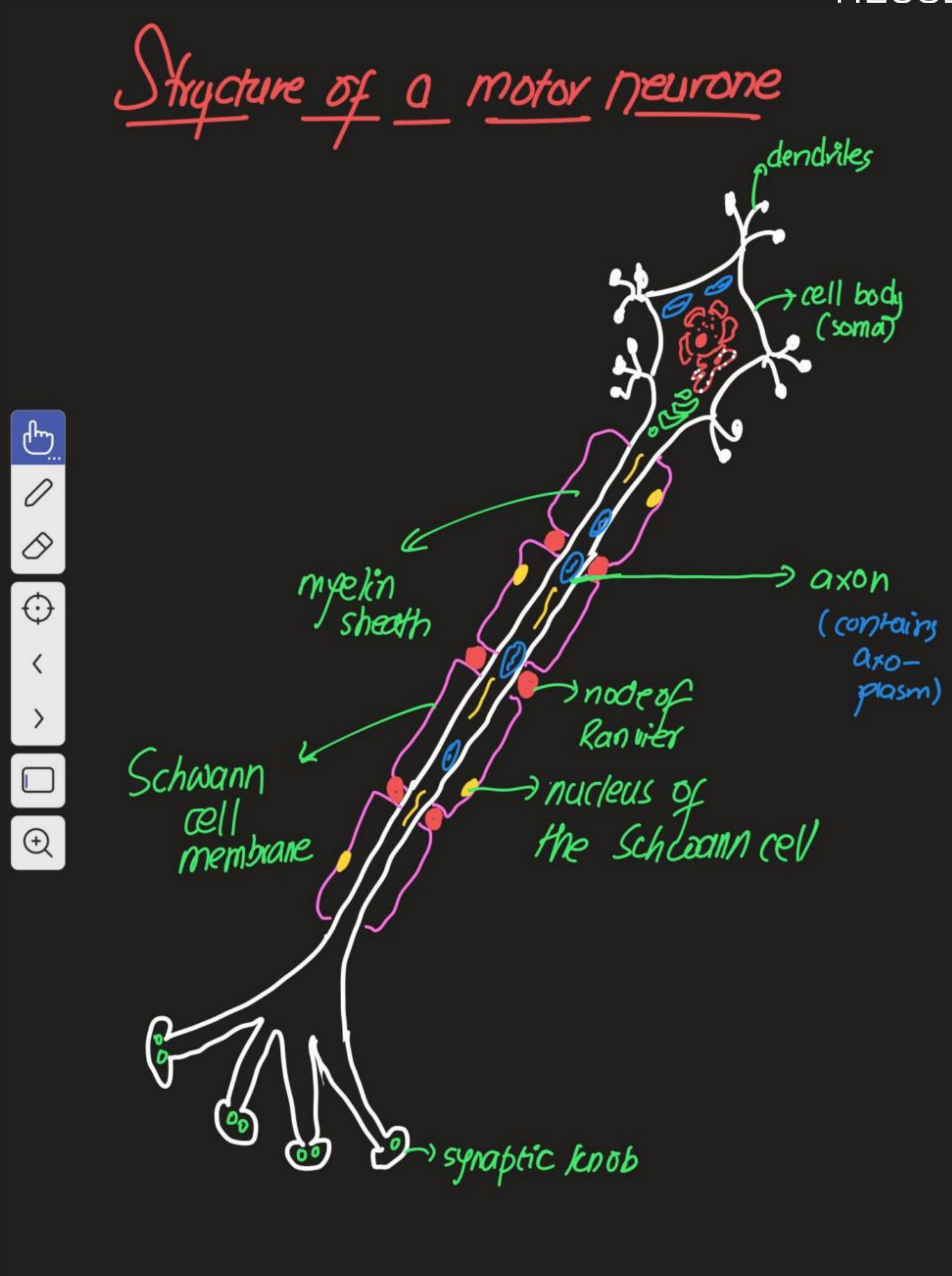
* Neurones are the basic unit or cells of the nervous system
* There are 3 basic types of neurones:

Ⓐ Motor neurone

Ⓑ Relay neurone

Ⓒ Sensory neurone

* A neurone has three basic parts;
  1) dendron / dendrites
  2) Cell body (soma)
  3) Axon


Structure of a motor neurone
dendrites
cell body (soma)
myelin sheath
axon (contains axo-plasm)
node of Ranvier
Schwann cell membrane
nucleus of the Schwann cell
synaptic knob

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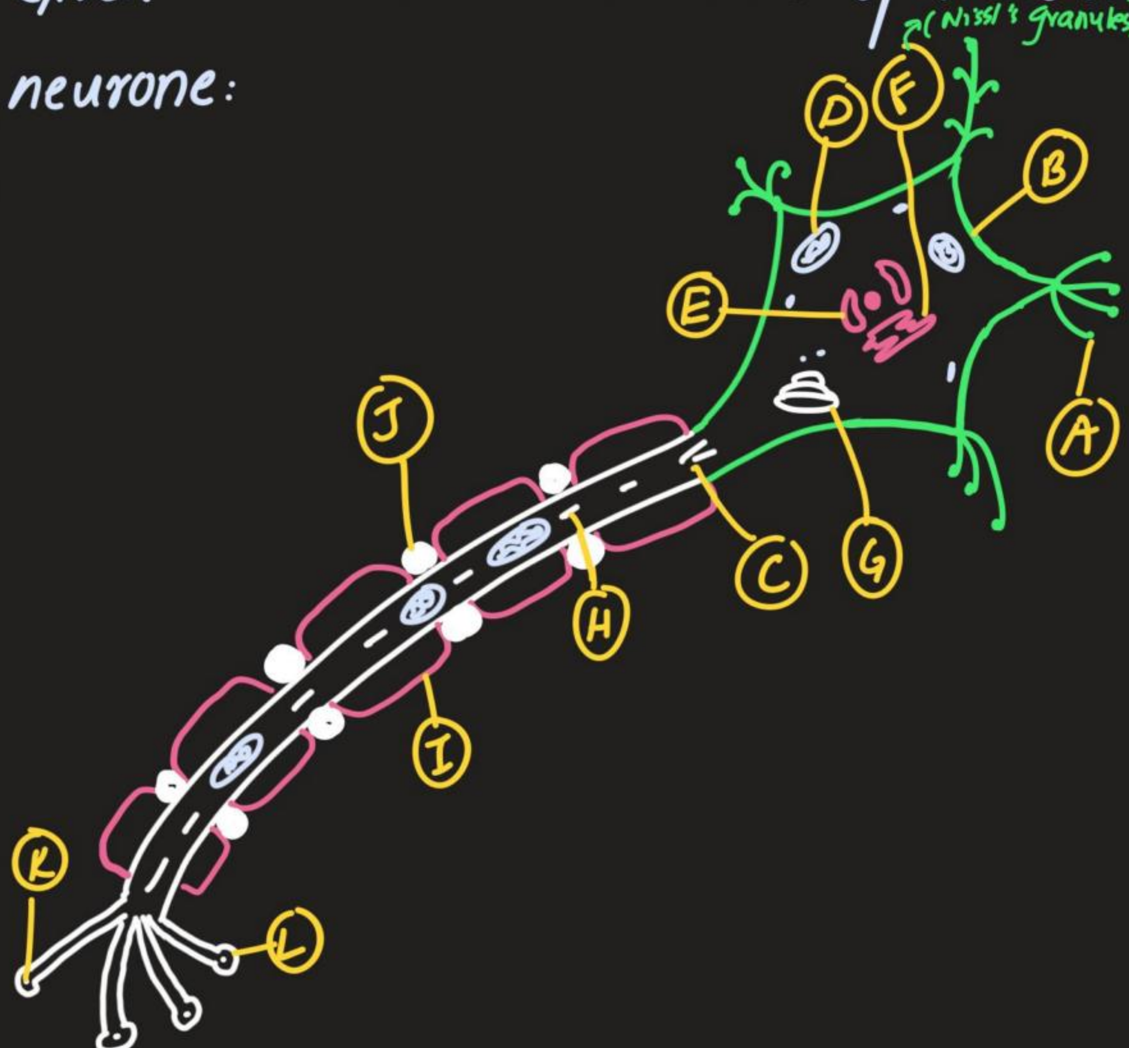
Structure of a motor neurone

* Given below is the structure of a motor neurone:



(A) Dendrites

(B) Cell body

(C) Axon

(D) Mitochondrion

(E) Nucleus

(F) Nissl's granules (rER)

(G) Golgi Apparatus

(H) Microtubules

(I) Myelin sheath

(J) Node of Ranvier

(K) Vesicle of neurotransmitter

(L) Axon terminal

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Function of different parts of the neurone:

* All neurones have the following 3 components:

(A) Dendrites/Dendron

(B) Cell body

(C) Axon

* The segment of the neurone that takes impulses towards the cell body is known as the dendron/dendrite

* The segment of the neurone that takes impulses away from the cell body is known as the axon.

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* The segment of the neurone which receives impulses from the dendrite and sends them towards the axon is known as the cell body.

Cell body:

* The cell body is also termed as the soma.
* Structures within the cell body include:

(a) Mitochondria (b) rER (c) Nucleus

(d) Golgi body

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a) Mitochondria

is responsible for producing energy in the form of ATP. This energy is used for:

1. Synthesis of neurotransmitters
2. Movement of vesicles from the cell body towards the axon terminal.
3. Na^+-K^+ pump.
4. Reuptake of neurotransmitter.

Mitochondria are also present within the axoplasm of the neurone.

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b) rER

within the neurone is modified to form the Nissl's granule. rER is responsible for protein synthesis within the cell body

c) Nucleus

contains the genetic material in the form of DNA within the neurone. The genes on nuclear DNA code for proteins that are essential for the transmission of nerve impulses along a neurone.

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d) Golgi body

serves to modify the proteins and package them into vesicles.

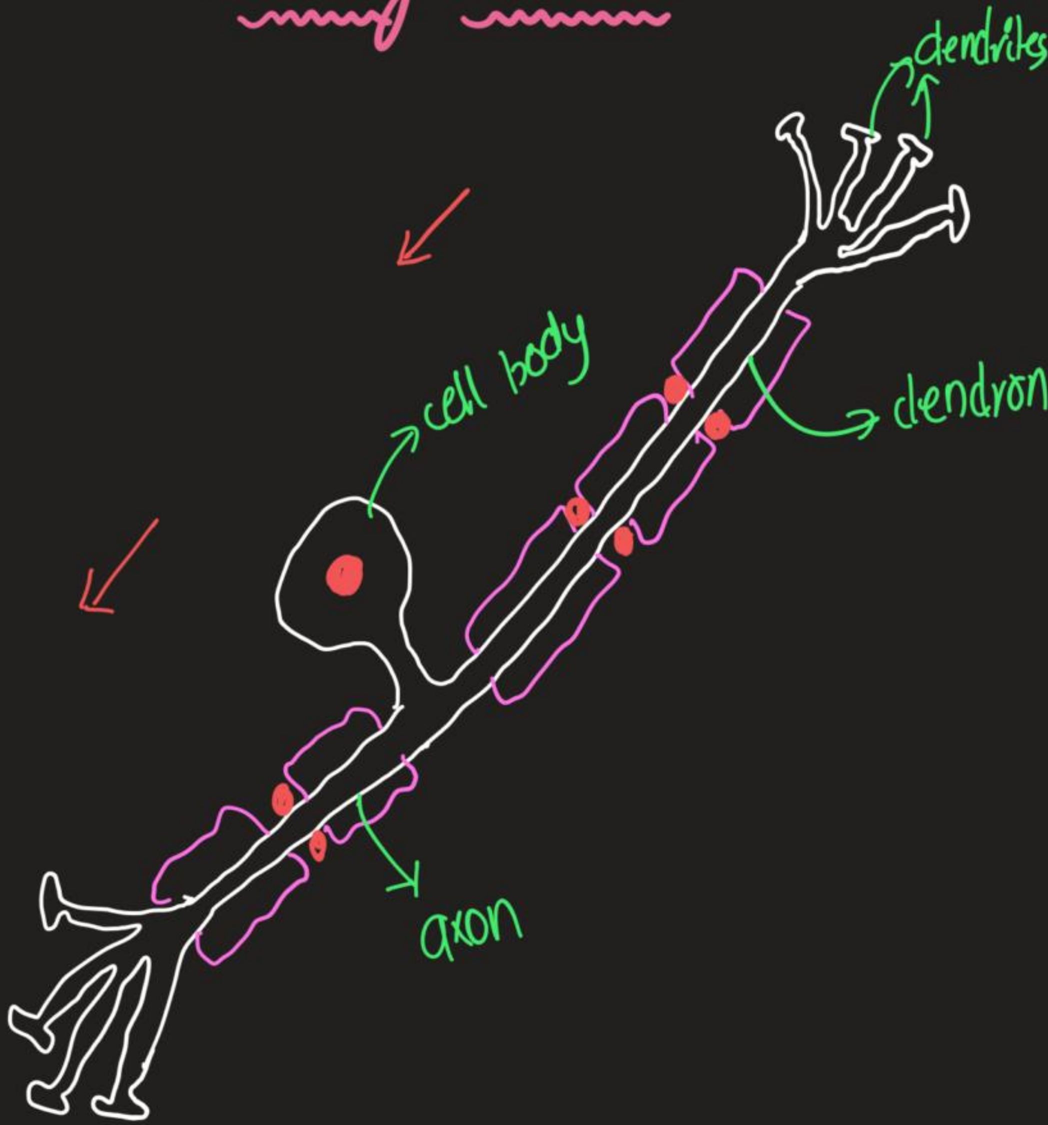
* Neurones are devoid of centrioles and therefore do not divide by mitosis.

Myelin sheath and Node of Ranvier

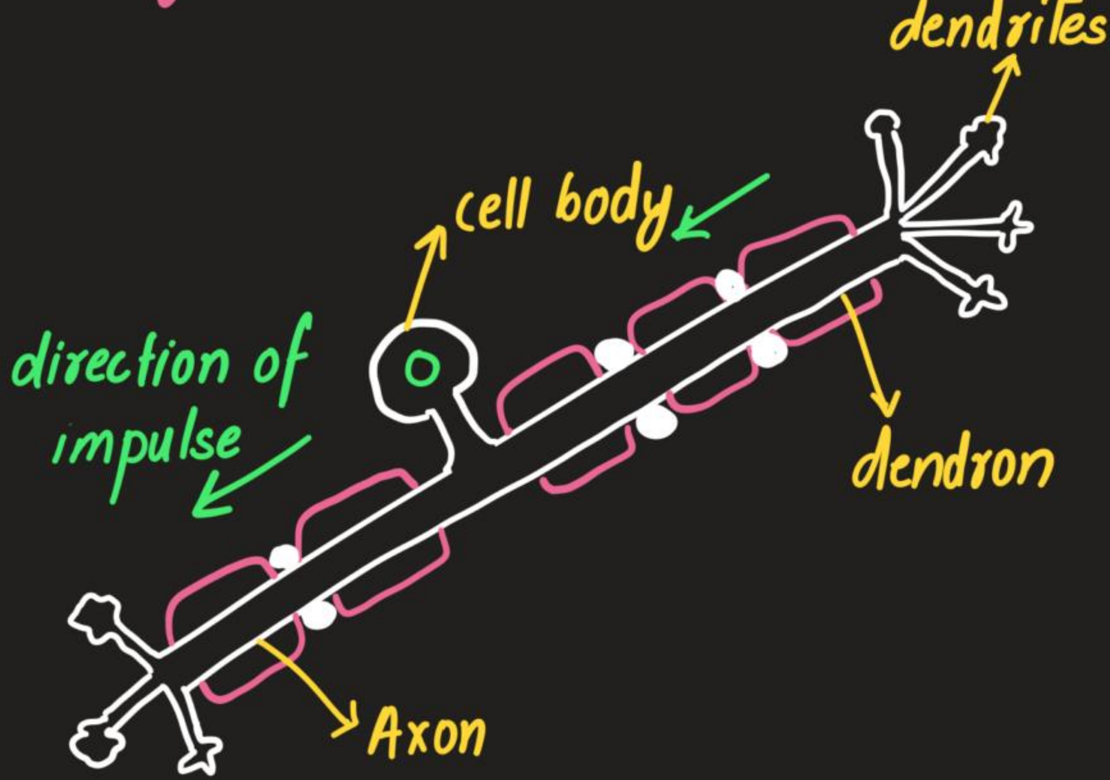
* Myelin sheath insulates the axon and enables rapid transmission of electrical impulses along a neurone.

* Nodes of Ranvier allow diffusion of ions in and out of the neurone enabling electrical impulses to travel along the axon.

Sensory Neurone

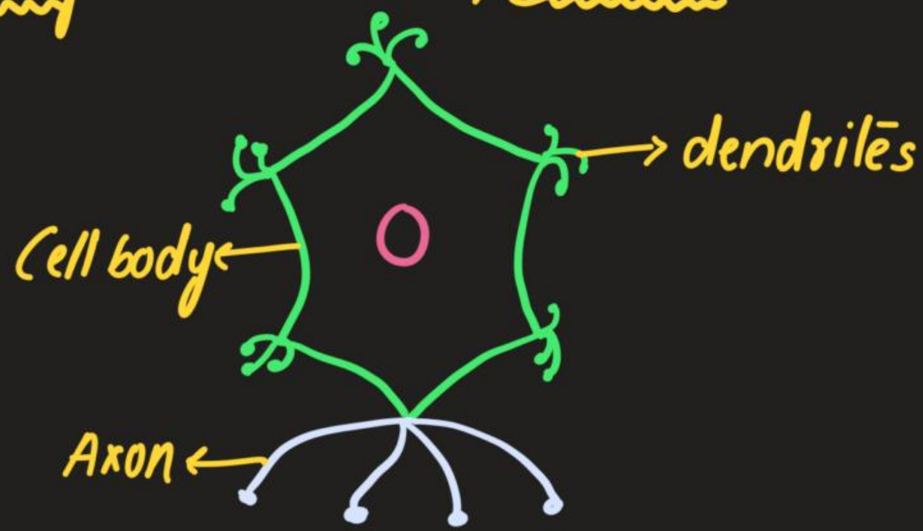


Sensory Neurone



- long dendron
- relatively shorter axon
- cell body lies at the centre of the neurone

Relay (intermediate) neurone



- short dendrites
- long or short axons
- variable size

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Q1: Compare and contrast the structure & function of a sensory and motor neurone.

Similarities

1) Both have a cell body
2) Both have dendrites to take the impulses towards the cell body.
3) Both have an axon which transmits the impulses away from the cell body.

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Differences:

1) Sensory neurones have a relatively longer dendron whereas motor neurones have short dendritic branches.

2) Sensory neurones have a relatively shorter axon whereas motor neurones have a long axon.

3) The cell body of a sensory neurone is located along the centre of the neurone whereas the cell body of a motor neurone is located towards one end of the neurone.

4) Sensory neurone carries the impulses towards the central nervous system whereas motor neurone transmits the impulses away from the central nervous system.

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Q2: Describe the structure of a motor neurone? [7 marks]

Ans: A motor neurone is made up of dendrites, a cell body and an axon. The dendrites are responsible for transmitting electrical impulses towards the cell body. Cell body contains the nucleus, rER (Nissl's granules), Golgi apparatus and numerous mitochondria. The axon takes impulses away from the cell body. The axon is much longer

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than dendrites. It is insulated by myelin sheath which is interrupted at regular intervals by the nodes of Ranvier. The ends of the axon (synaptic knobs / terminals) contain numerous vesicles containing neurotransmitter.

Q3: Describe the structure of a myelinated sensory neurone? [7]

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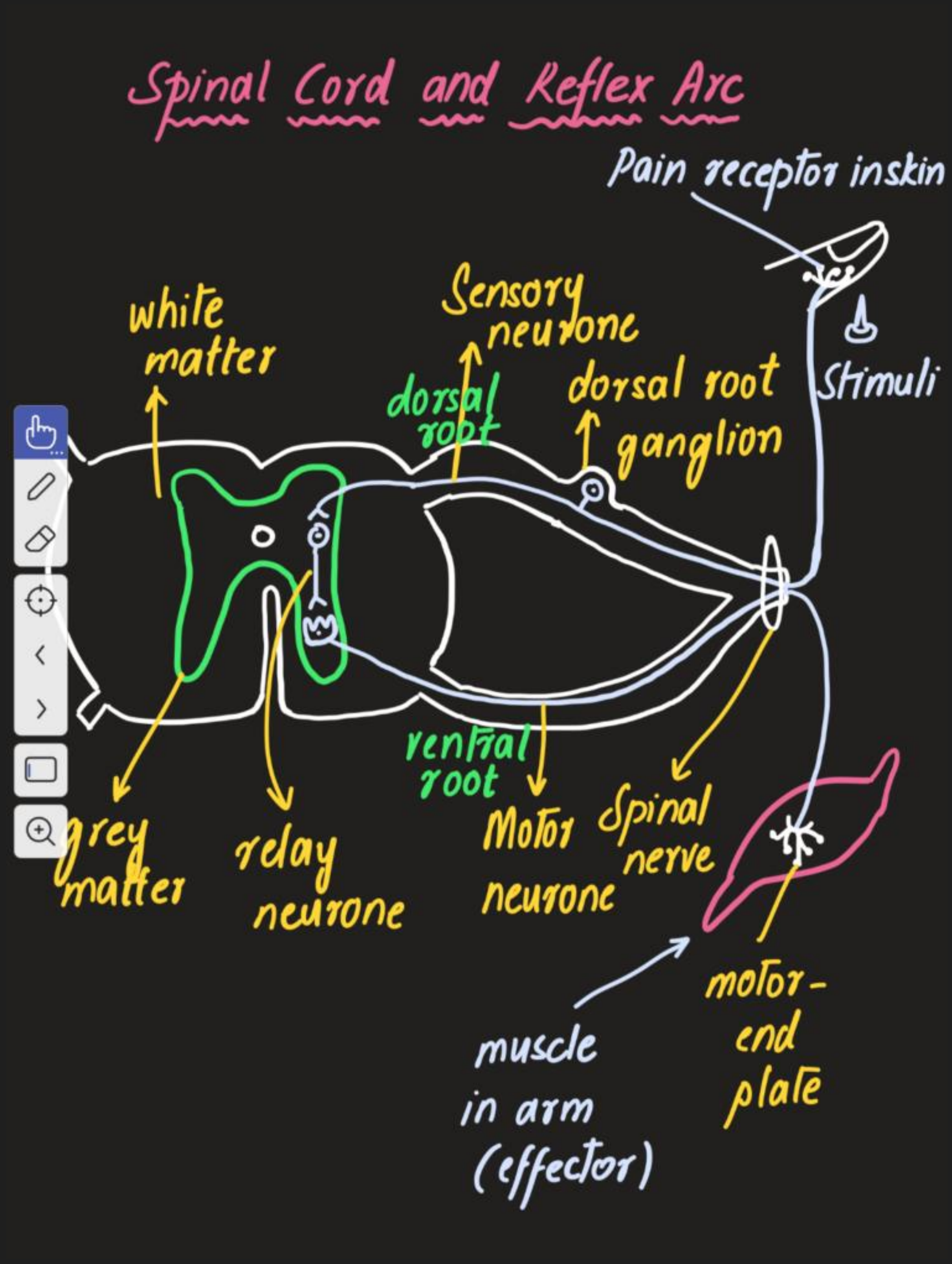
Control & Coordination



With

Mohammad Hussham Arshad, MD

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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Reflex arc & it's significance
- Introduction to resting membrane potential

Video Lecture 2 Slides

Mohammad Hussham Arshad, MD
Biology Department

CONTROL AND COORDINATION

(A) Nervous System

(B) Female Reproductive System

(C) Musculoskeletal System

(D) PGRS → Gibberellins
→ Auxins

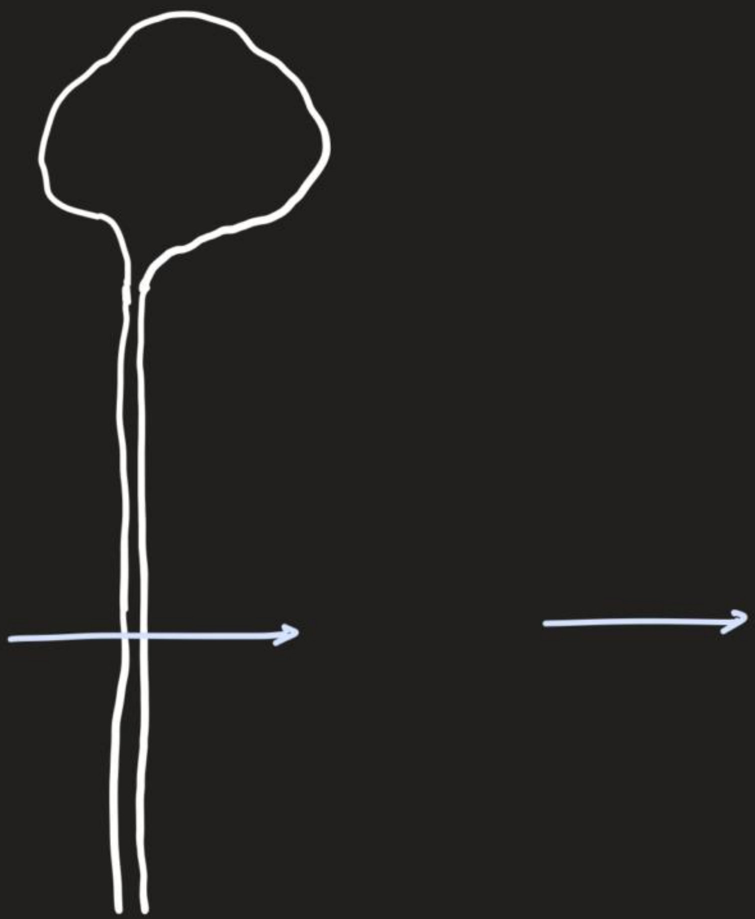
(E) Electrical co-ordination in plants
→ Venus fly trap

Nervous System:

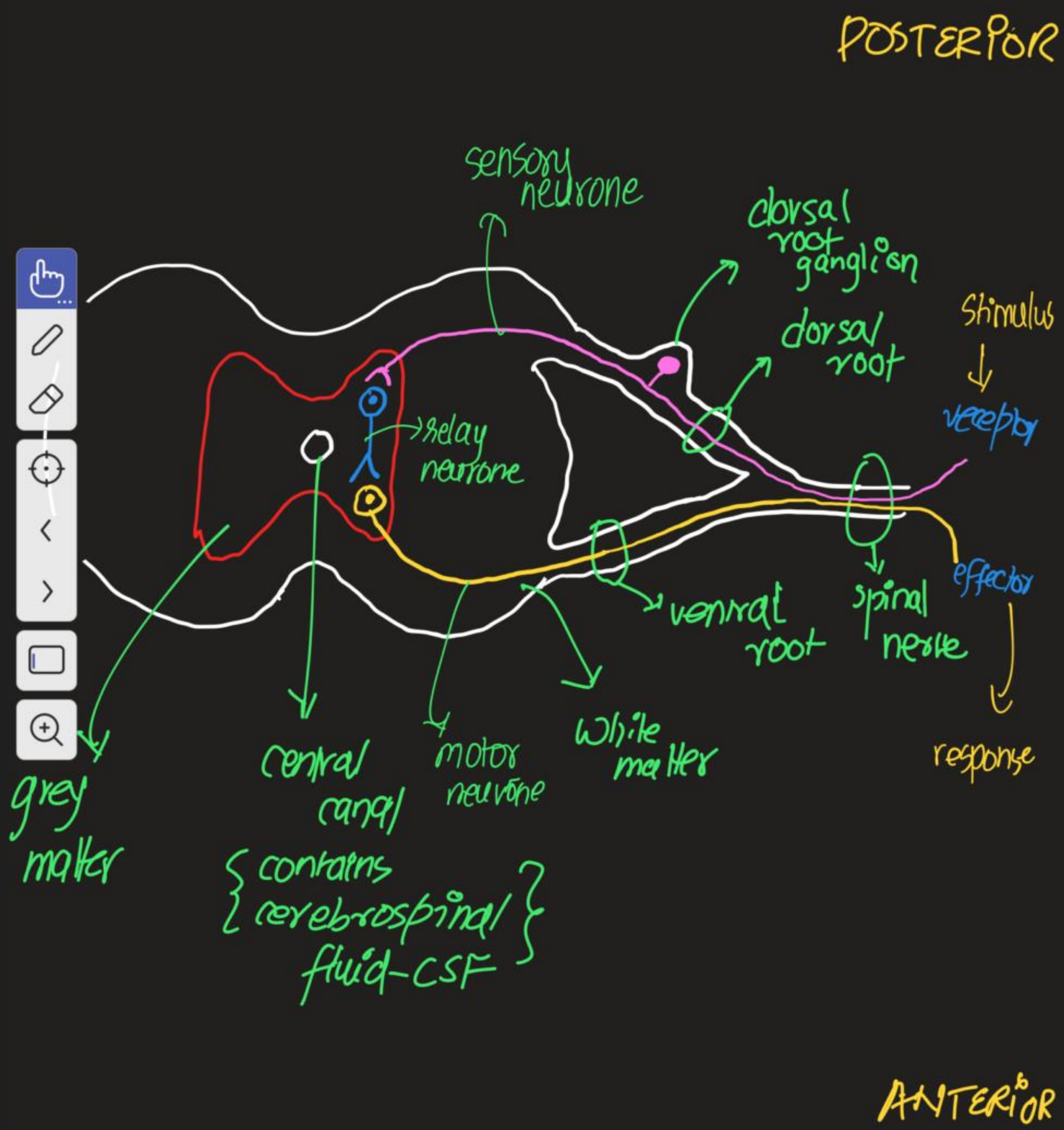
* Classification
* Neurones → Structure and types
* Functions of the different parts of a neurone

Spinal Cord and the Reflex Arc

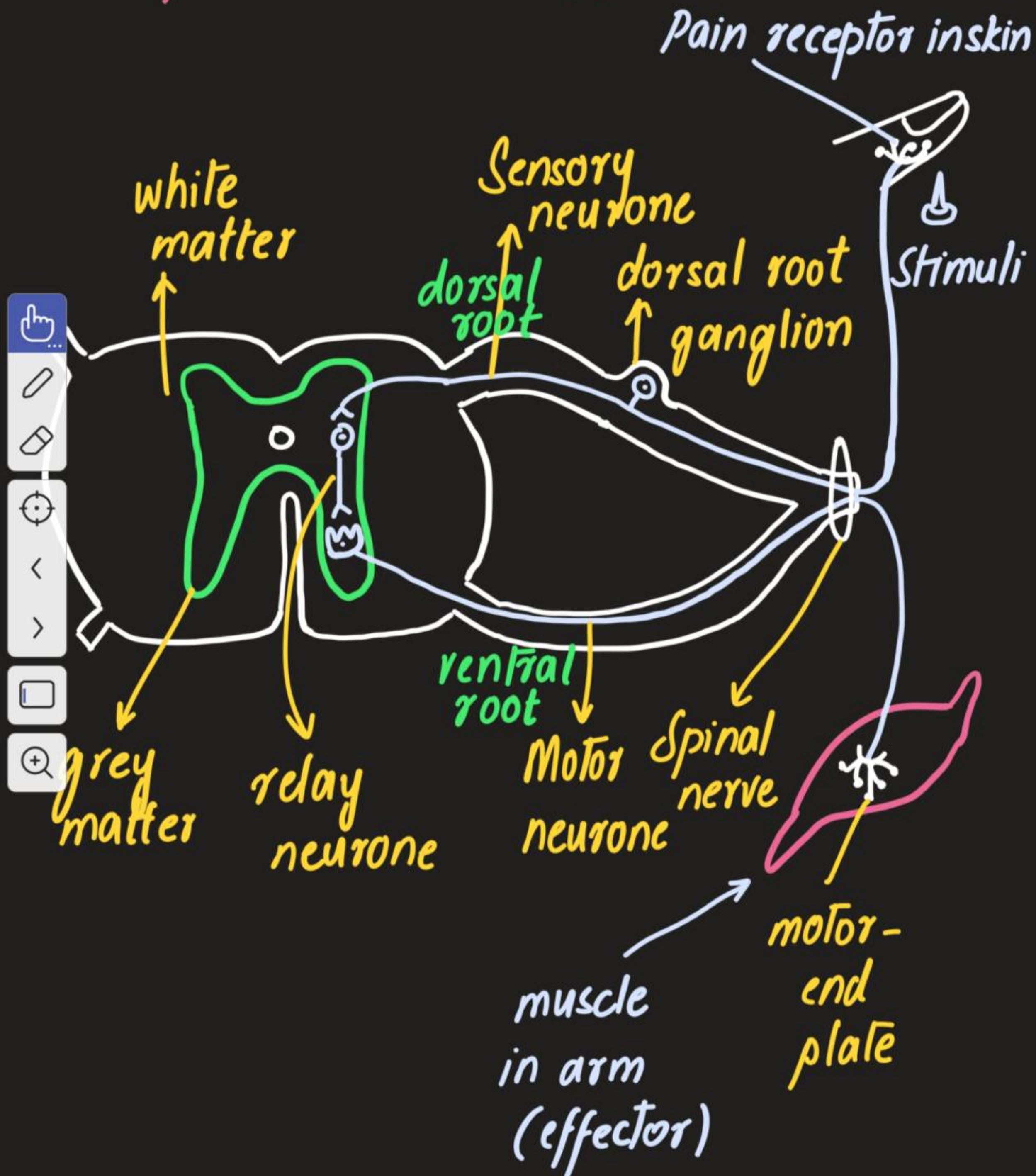
Spinal Cord

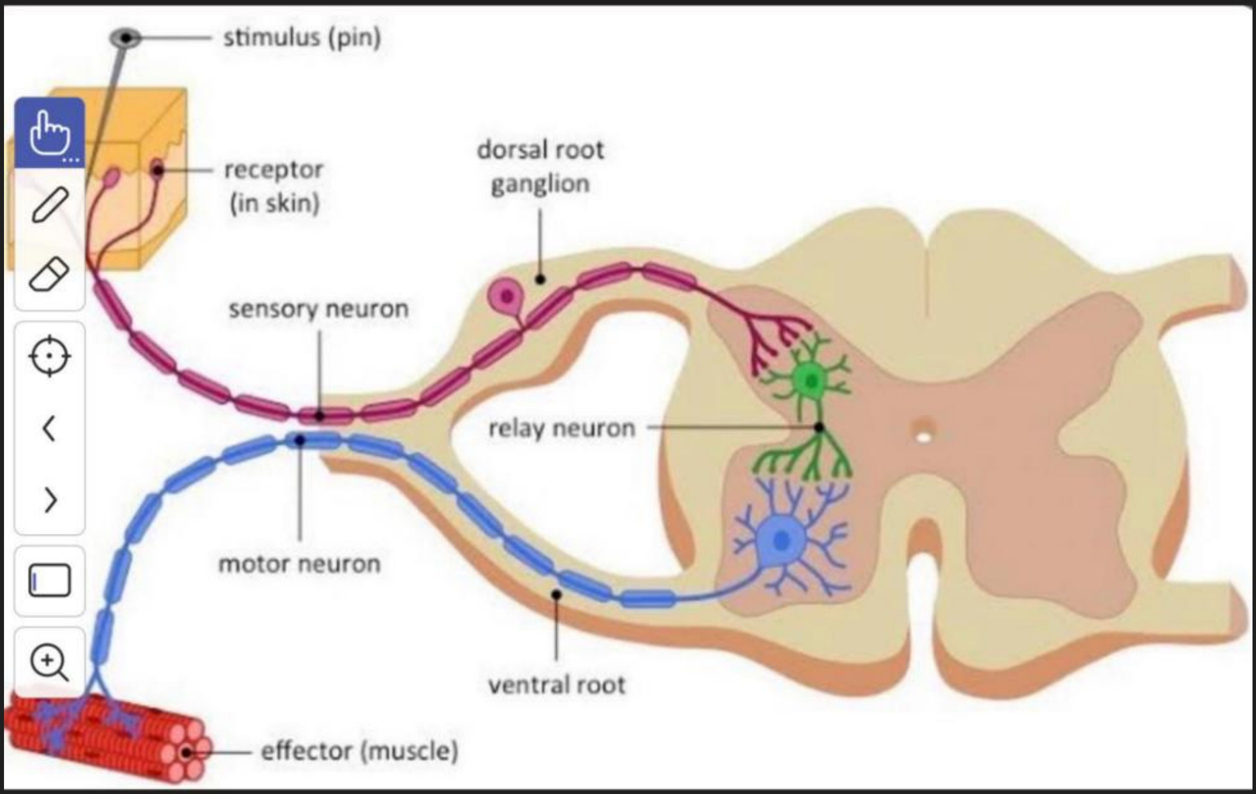


T.S. of spinal cord



Spinal Cord and Reflex Arc




stimulus (pin)
receptor
(in skin)
dorsal root
ganglion
sensory neuron
relay neuron
motor neuron
ventral root
effector (muscle)

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Q1: What are the components of a reflex arc?

Ans: Reflex arc involves rapid involuntary transmission of information from the receptors to the effectors. The sensory neurone receives input from the receptors and passes the electrical impulse to the relay neurones within the spinal cord. Relay neurone sends information to the motor neurones. Motor neurone sends information to the effectors which carry out the required response.

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Q2: Briefly describe the role of the three types of neurones in the reflex arc?

Ans: **Sensory Neurone**: Receives electrical impulses (action potential) from the receptors and pass it to the spinal cord.

Intermediate Neurone: Receives electrical impulses (action potential) from the sensory neurone and relays it to motor neurones.

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Motor Neurone: Carries electrical impulses (action potential) from the spinal cord to the effectors.

3: What's the significance of the reflex arc to humans?

Ans: 1. Reflex arc involves a simple circuitry

2. It's rapid

3. It's involuntary

4. It's innate (unlearned)

5. It's stereotypical

6. It protects from harm.

Q4: Describe how a spinal reflex arc functions and explain why is it an advantage to a mammal. [9 marks].

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3 Fig. 3.1 is a diagram of a reflex arc.

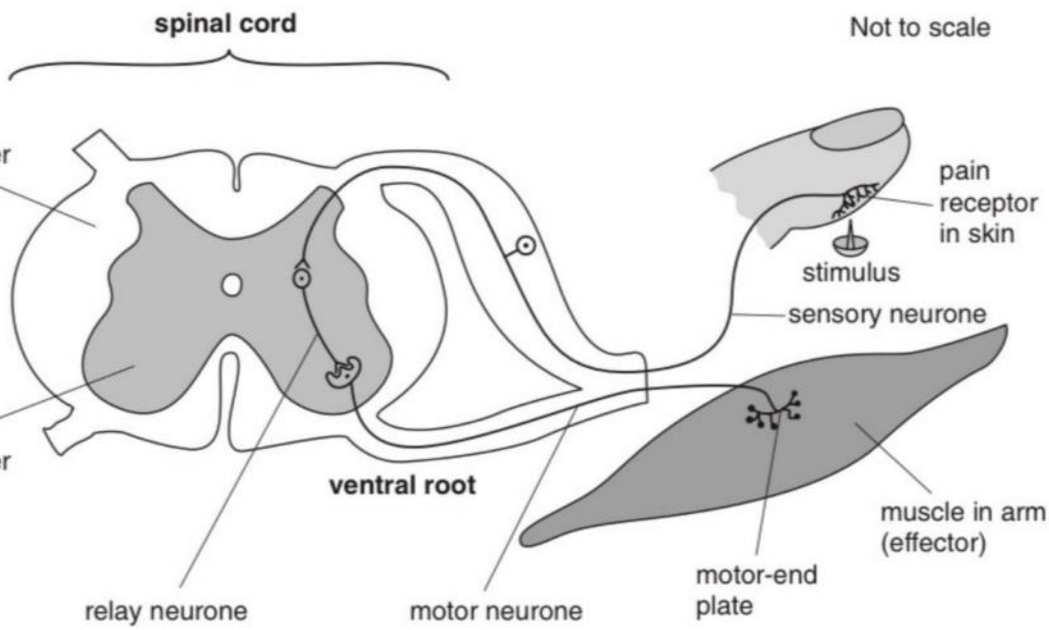


Fig. 3.1

(a) Explain **briefly** how the stimulus at the finger produces an impulse in the sensory neurone.

....

....

....

.... [3]

(b) Describe the role of the motor neurone in the reflex arc.

* motor neurone synapses with the relay neurone in the spinal cord
* transmits information away from the spinal cord
* towards the effector which carries out the response [3]

(a) Most reflex arcs pass through the spinal cord and involve different types of neurones.

Name **and** state the functions of the three types of neurone in a spinal reflex arc.

(1) Sensory neurone → transmits impulses from the receptor to the spinal cord

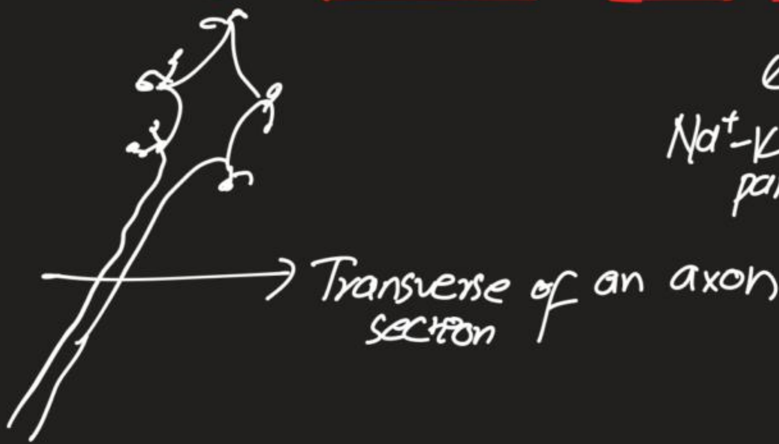
(2) Relay neurone → transmits impulses from the sensory n. to the motor n.

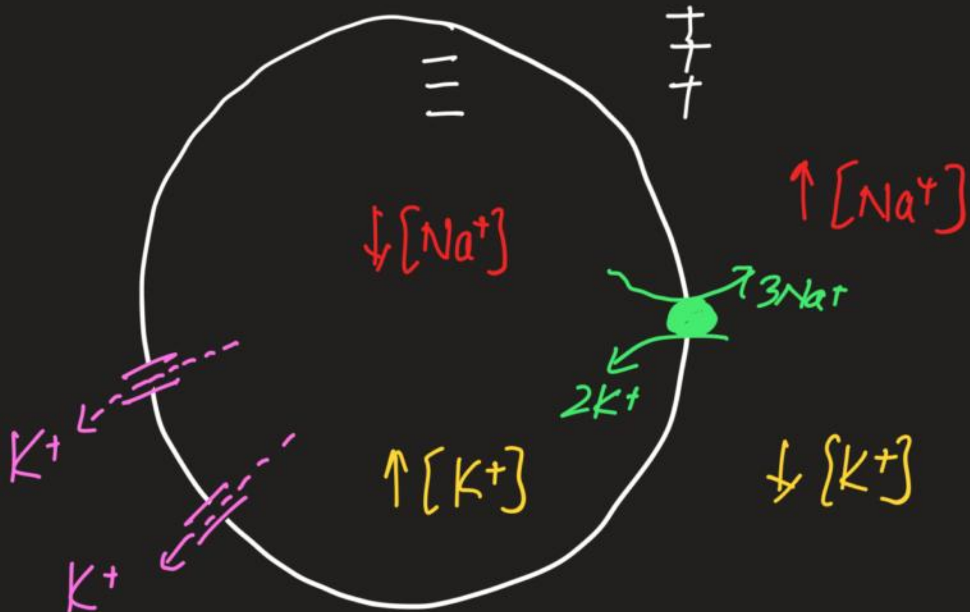
(3) Motor neurone → transmits impulses from the spinal cord to the effectors [3]

Resting membrane potential (RMP), Action potential and the refractory period

Distribution of ions across the neuronal membrane and RMP

- Na^+-K^+ pump
- 'leaky' K^+-channels





"leaky" K^+-channels

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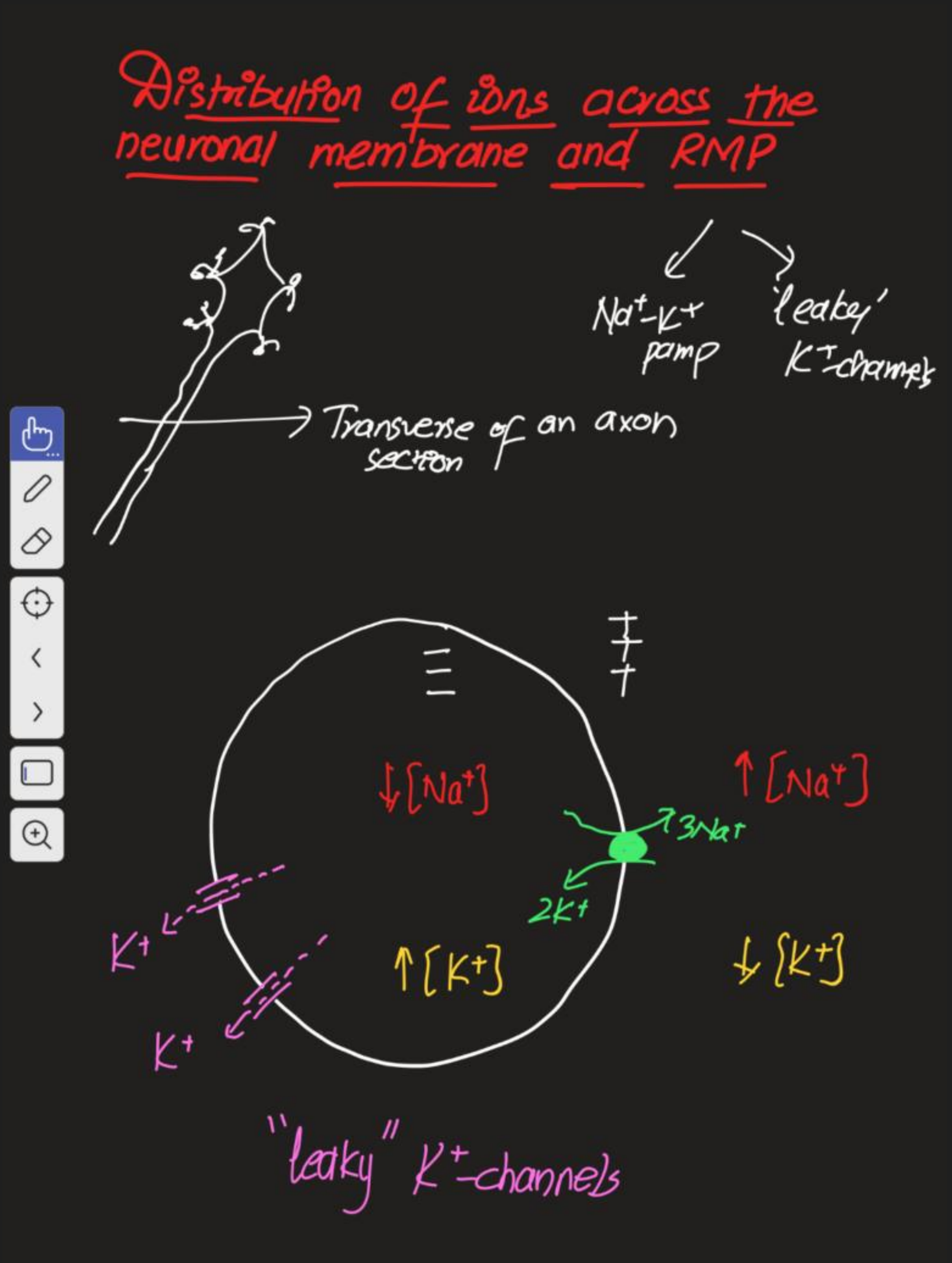
Control & Coordination



With

Mohammad Hussham Arshad, MD

ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Voltage gated channel proteins
- Action potential

Video Lecture 3 Slides

Mohammad Hussham Arshad, MD
Biology Department

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Nervous System:

* Classification
* Neurones → Structure and types
* Functions of the different parts of a neurone
* Spinal cord and the reflex arc
* Significance of reflex arc
* Resting membrane potential (RMP)

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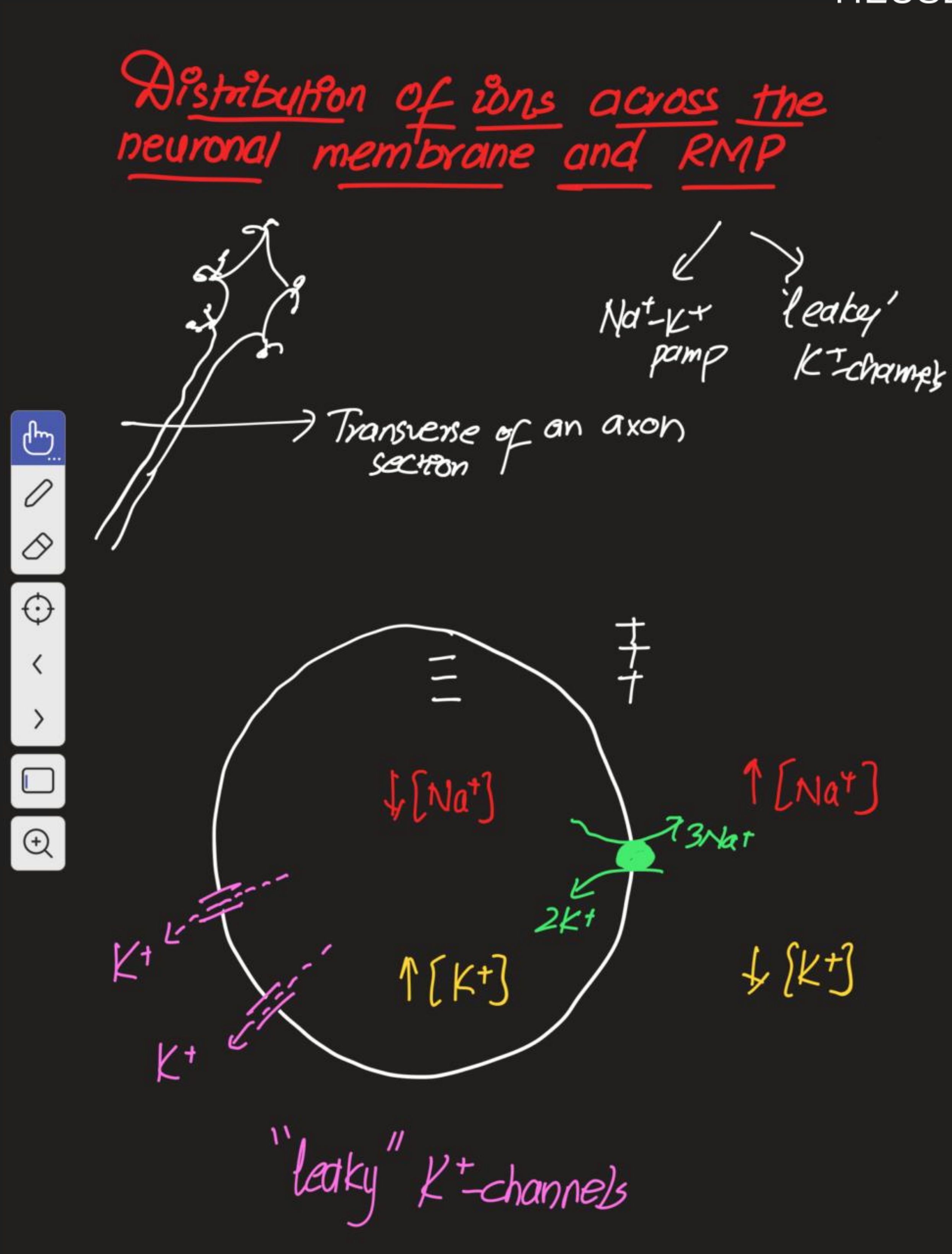
Resting membrane potential (RMP), Action potential and the refractory period


Distribution of ions across the neuronal membrane and RMP
Na+-K+ pump
'leaky' K+-channels
Transverse section of an axon
↓[Na+]
↑[Na+]
3Na+
2K+
↑[K+]
↓[K+]
K+
K+
"leaky" K+-channels

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* When the neurone is at rest (not carrying an electrical impulse), the Na^+- K^+ pump & the leaky K^+-channels maintain a potential difference across the axonal membrane.

* Na^+-K^+ pump is a transmembrane protein. It pumps $3Na^+$ outside and $2K^+$ into the cell against the concentration gradient.

* The 'leaky' K^+-channels allow slow movement of K^+ out of the cell.

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* The inside of the cell is therefore more negative than the outside of the cell (due to loss of +vely charged ions)

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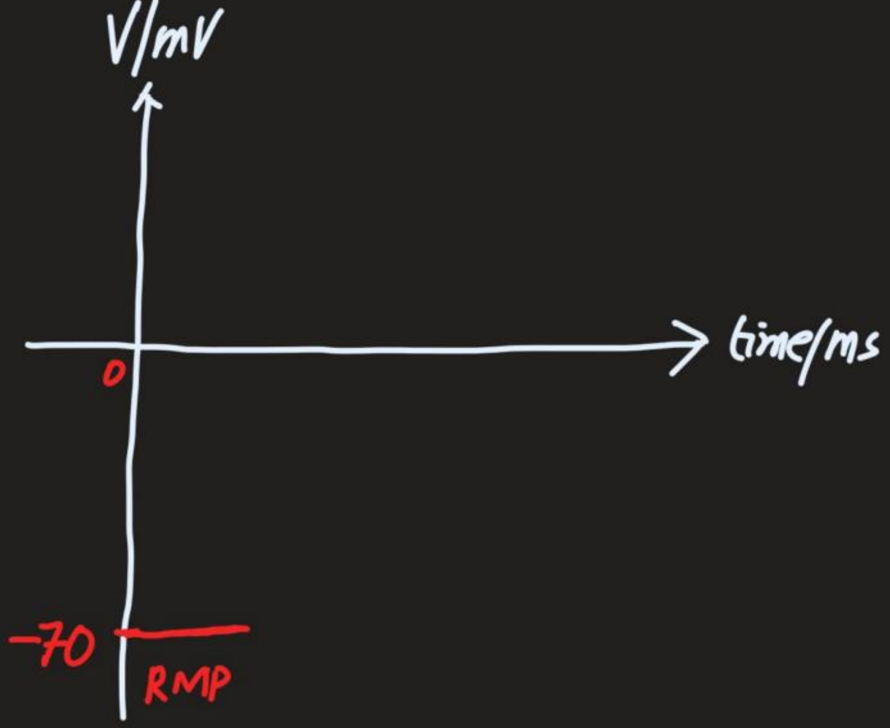
* The potential difference across the neuronal membrane at rest is known as the resting membrane potential (RMP);

⇒ approx = − 70 mV



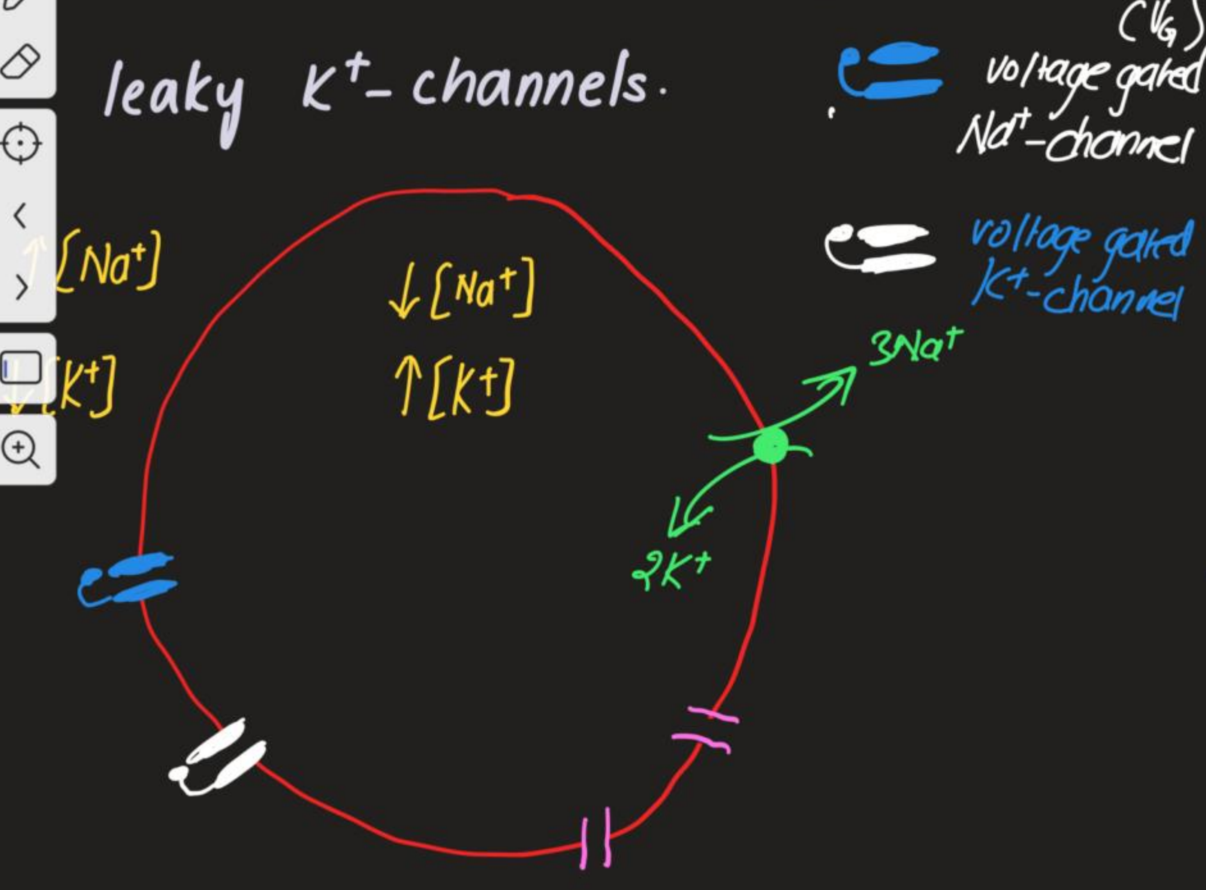
Q1: Outline how the resting membrane potential is maintained? [7 marks]

Ans: The axonal membrane is phospholipid bilayer which contains the Na^+–K^+ pump and leaky K^+ channels which are responsible for maintaining the resting membrane potential. The Na^+–K^+ pump is a transmembranous protein. It pumps $3Na^+$ ions outside and $2K^+$ ions into the cell against the concentration gradient. The leaky

K^+ ion channels allow gradual loss of K^+ ions from the cell down the conc. gradient. The Na^+–K^+ pump and the leaky K^+ channels therefore maintain a negative resting membrane potential of -70mV. The maintenance of the RMP is an active process.

Additional proteins on the neuronal membrane

* The axonal membrane contains many other transport proteins in addition to Na^+–K^+ pumps and the leaky K^+-channels.



* The proteins are channel proteins with 'gates' that open and close when the potential difference across the membrane changes (due to stimulus). Thus, these proteins are termed as voltage-gated channels.

OG → gate

* There are two types of voltage-gated channels:

(A) Voltage-gated Na^+ (VG) - channels

(B) Voltage-gated K^+ (VG) - channels

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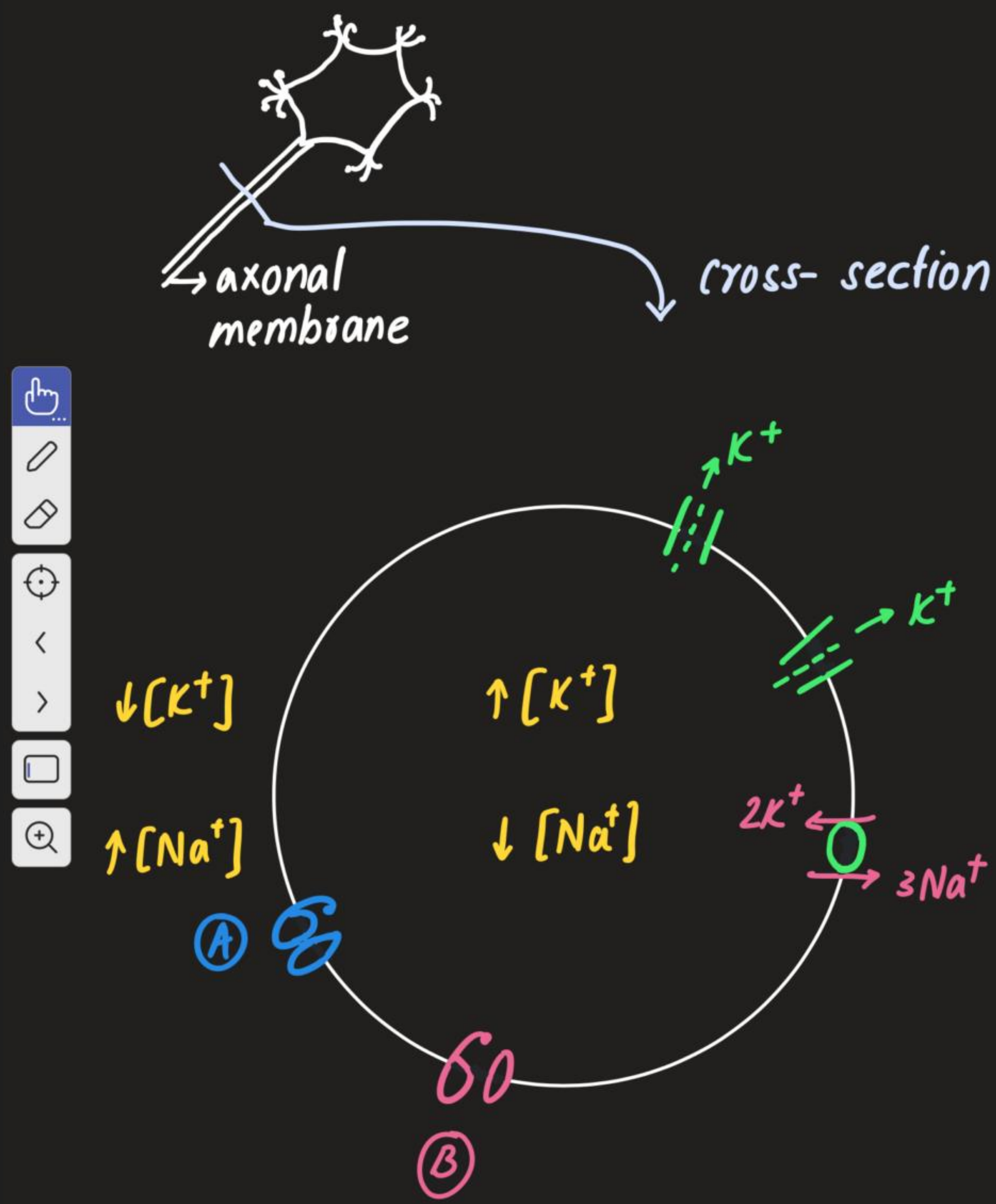

Key:

0g voltage gated Na^+- channel } close at resting membrane potential (RMP)

0g voltage gated K^+- channel }

= leaky K^+- channel] open at RMP

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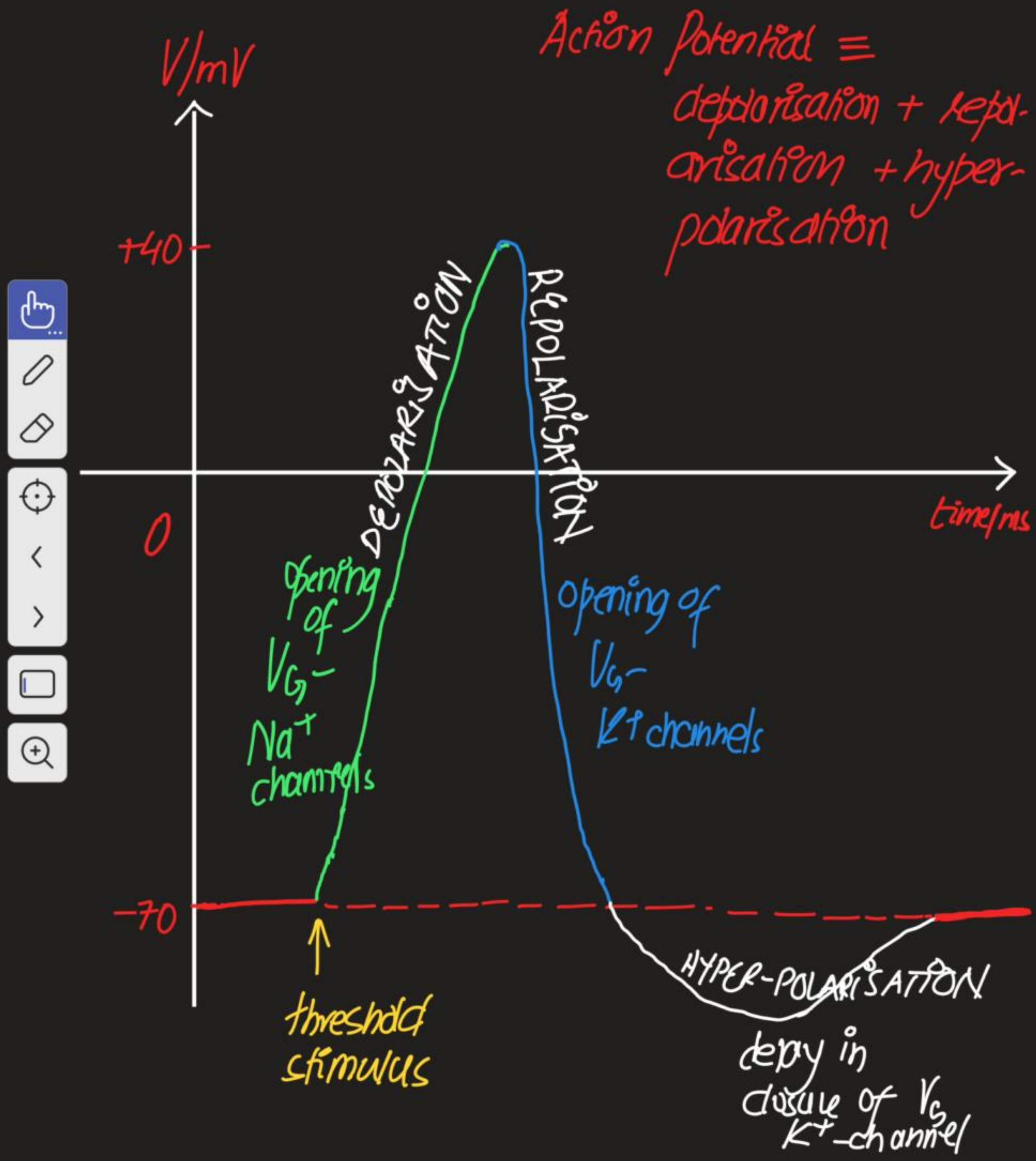
* When (A) opens → Na^+ diffuse **INTO** the cell via positive feedback

* When (B) opens → K^+ diffuse **OUT** of the cell

ACTION POTENTIAL



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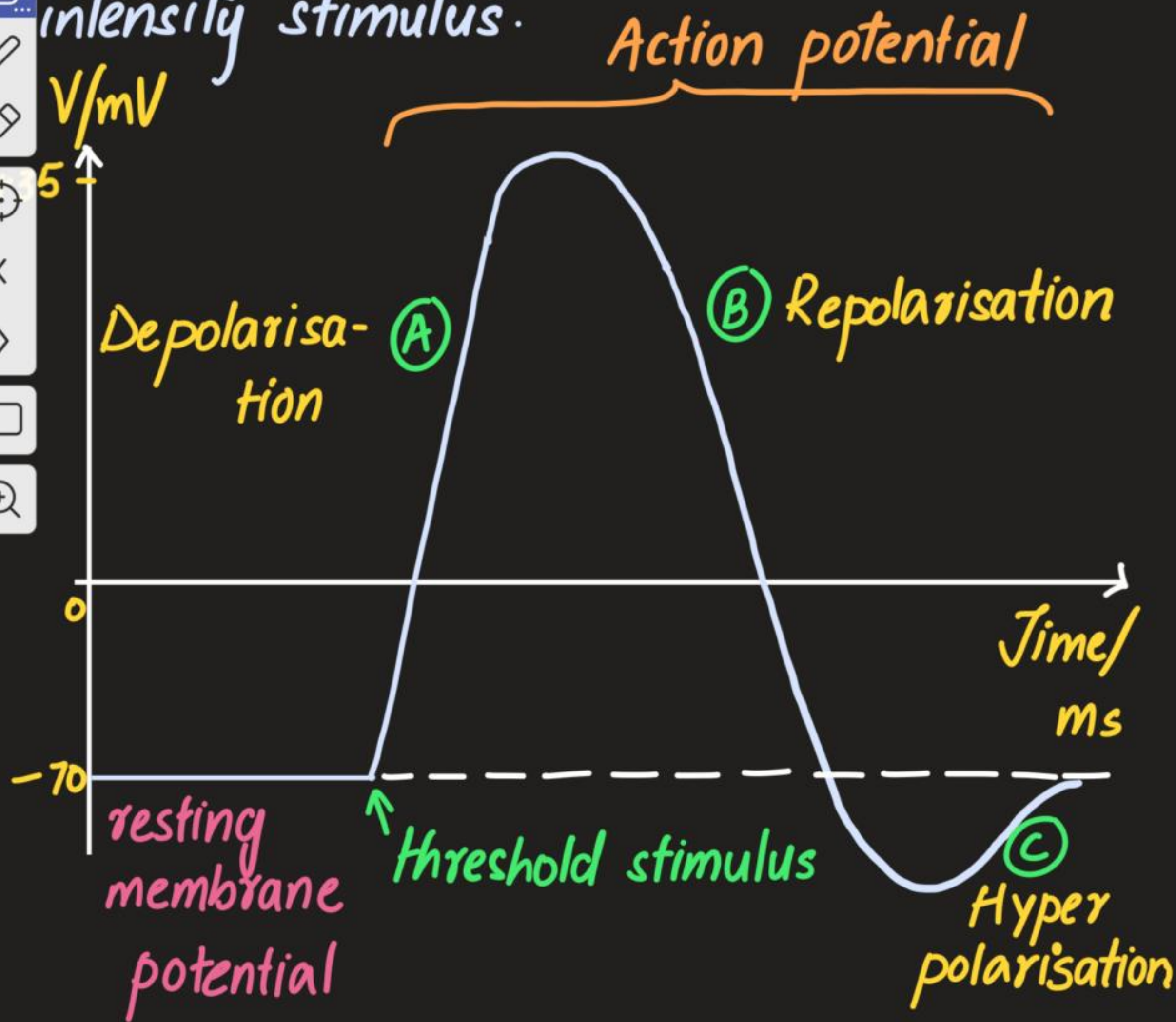
ACTION POTENTIAL

* An action potential is a brief, large and reversible change in the resting membrane potential due to a threshold intensity stimulus.



Ⓐ + Ⓑ + Ⓒ = Action potential

Depolarisation → Ⓐ due to opening of V_G - Na^+ channels.

Repolarisation → Ⓑ due to opening of V_G - K^+ channels.

Hyper polarisation → Ⓒ delay in closure of V_G - K^+ channels

V_G = Voltage - gated

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Q2: Briefly describe the following events in action potential:

a) depolarisation

b) repolarisation

c) hyperpolarisation.

Ans: Phases of action potential:

Phase A : Depolarisation

- Depolarisation occurs due to opening of voltage gated Na^+-channels. These channels open and close in response to voltage changes.

- Opening of voltage-gated Na^+- channels allows rapid influx of Na^+ down the conc. gradient.

- The opening of V_G - Na^+ channels occurs via positive feedback effect.

Phase B : Repolarisation

- Repolarisation occurs due to opening of voltage gated K^+- channels.

- Opening of voltage-gated K^+- channels allows rapid efflux of K^+ down the conc. gradient.

- Loss of K^+ therefore causes the cell to be repolarised.

Phase C: Hyperpolarisation

- Hyperpolarisation results due to delay in the closure of $V_G - K^+$ channels. This causes the membrane potential to drop below resting membrane potential until these $V_G - K^+$ channels close.

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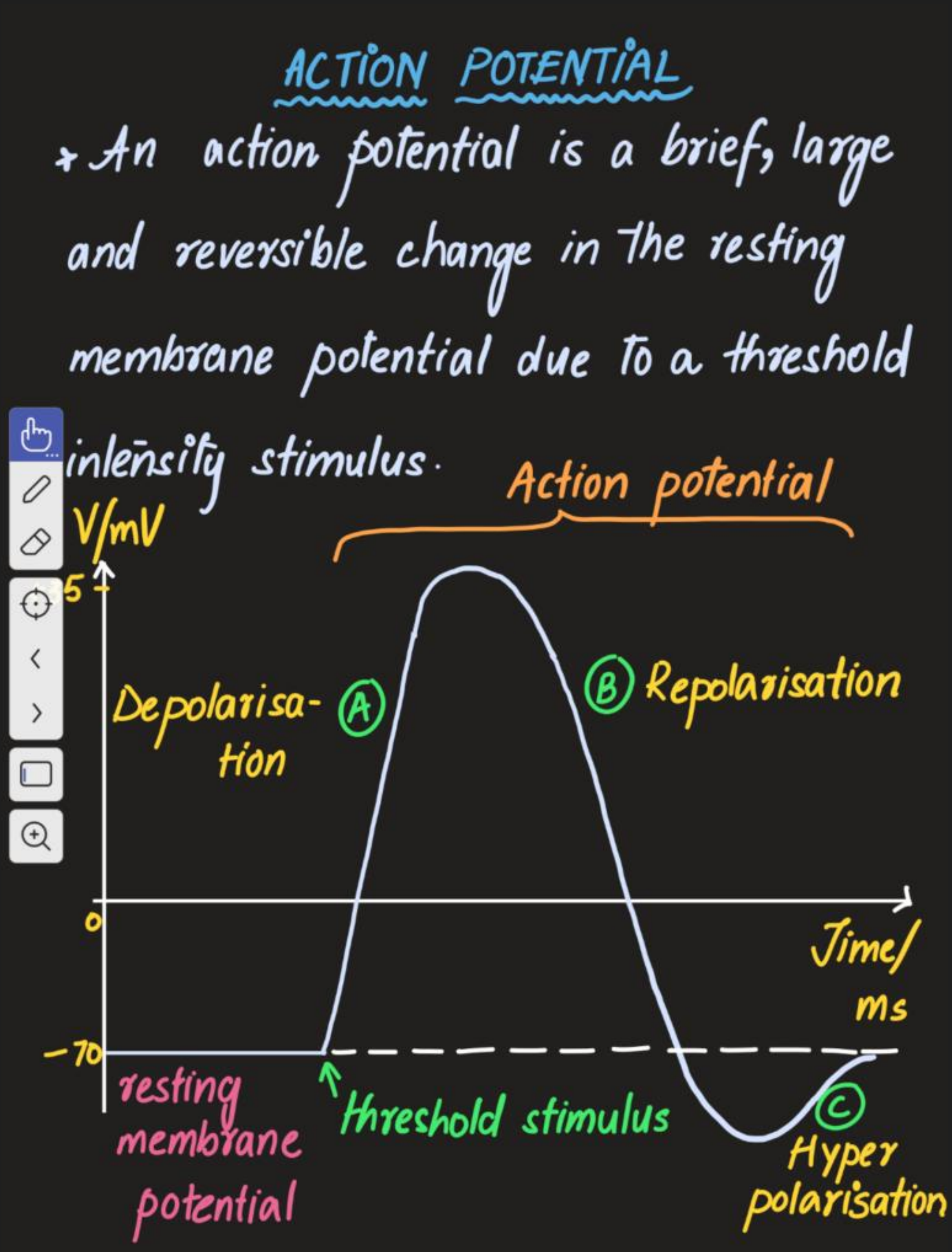
Control & Coordination



With

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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Threshold, subthreshold and suprathreshold stimuli
- Refractory period
- Factors affecting the speed of conduction

Video Lecture 4 Slides

Mohammad Hussham Arshad, MD
Biology Department

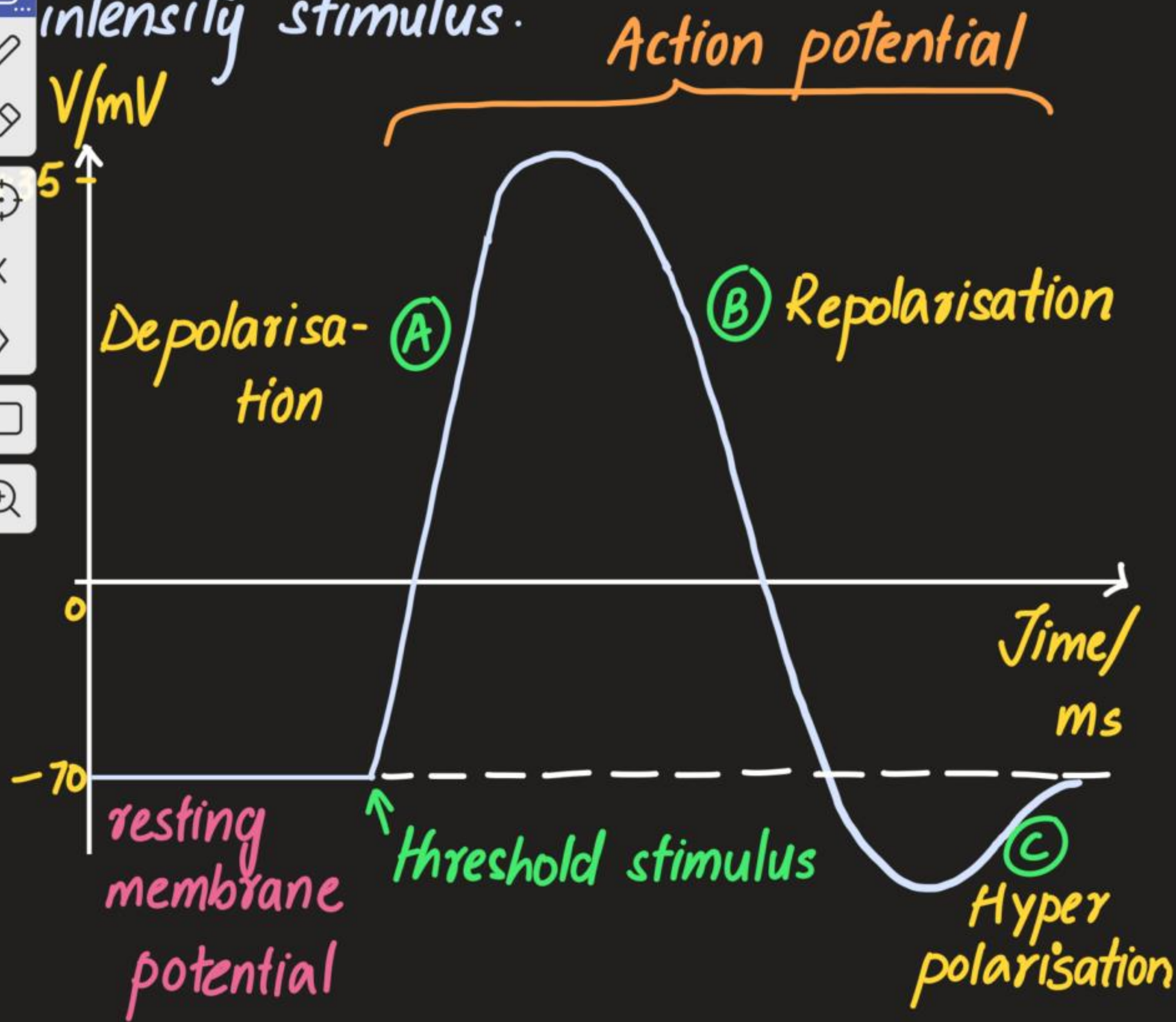
Nervous System:

* Classification
* Neurones → Structure and types
* Functions of the different parts of a neurone
* Spinal cord and the reflex arc
* Significance of reflex arc
* Resting membrane potential (RMP)
* Action potential

Resting membrane potential (RMP), Action potential and the refractory period

ACTION POTENTIAL

* An action potential is a brief, large and reversible change in the resting membrane potential due to a threshold intensity stimulus.



(A) + (B) + (C) = Action potential

Depolarisation → (A) due to opening of V_G - Na^+ channels.

Repolarisation → (B) due to opening of V_G - K^+ channels.

Hyper polarisation → (C) delay in closure of V_G - K^+ channels

V_G = Voltage - gated

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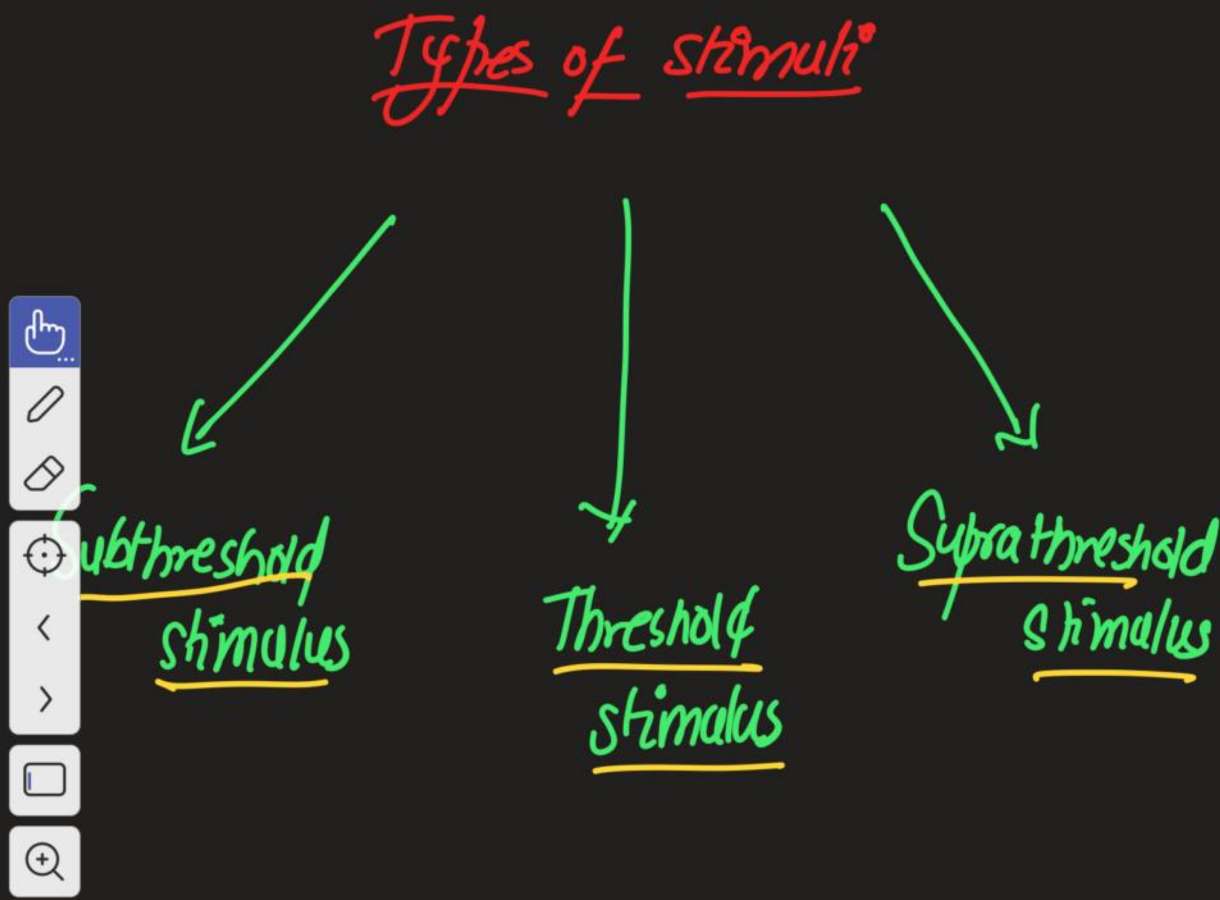
Types of stimuli
Subthreshold stimulus
Threshold stimulus
Suprathreshold stimulus

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TYPES OF STIMULI

- Stimuli can be classified based on their STRENGTH into the following three steps:

(a) Subthreshold Stimulus → stimulus which fails to initiate an action potential (AP)

(b) Threshold Stimulus → minimum strength of the stimulus required to initiate AP.

(c) Suprathreshold Stimulus → higher than threshold intensity stimulus.

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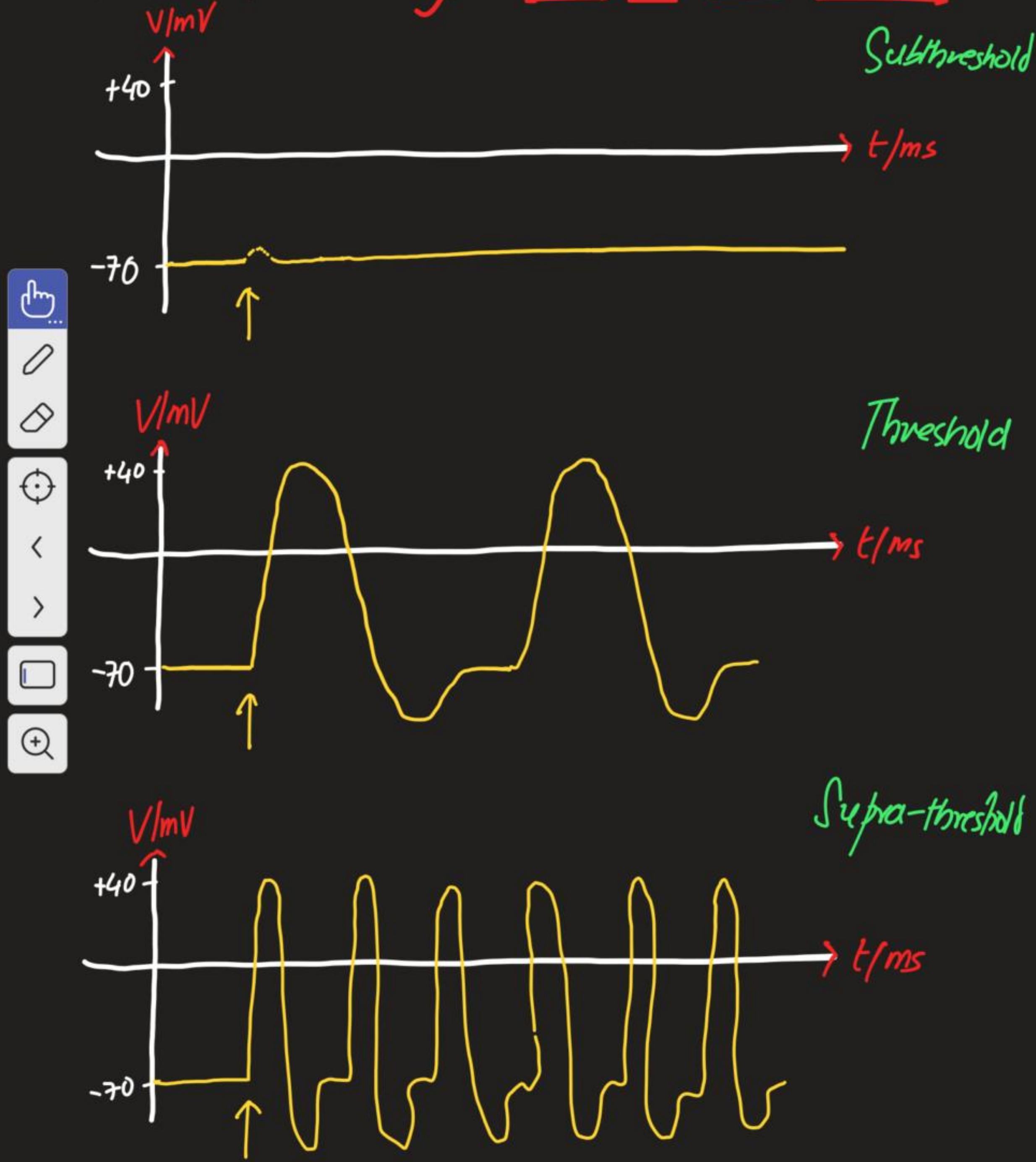
* Action potential is an ALL or NONE phenomenon. It either occurs or DOES NOT!

* There is no such thing as a strong or weak AP.

So how does a neurone distinguish between a strong and a weak stimulus?



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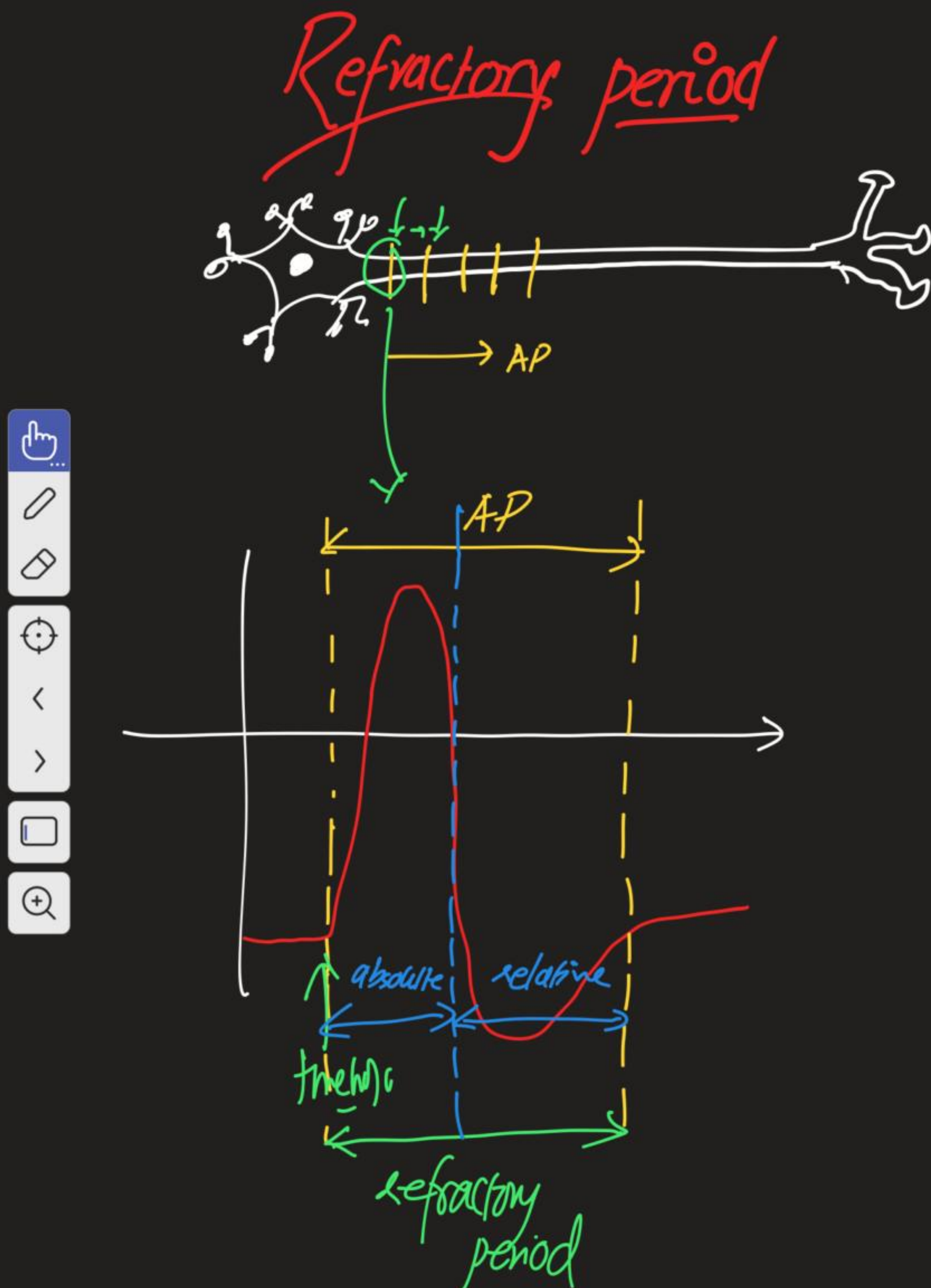
* Suprathreshold stimuli DO NOT change the shape/strength of the AP. They only shorten the duration of the AP.

* The greater the strength of the stimulus above the threshold, the greater is the frequency of action potentials.


Refractory period
AP
AP
absolute
relative
refractory period

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REFRACTORY PERIOD

* Refractory period is the duration of the action potential during which a threshold intensity stimulus CANNOT generate another action potential.

* Refractory period is subdivided into two phases:

(A) **Absolute Refractory Period**: during which a neuronal membrane cannot generate another AP irrespective of the intensity of the stimulus.

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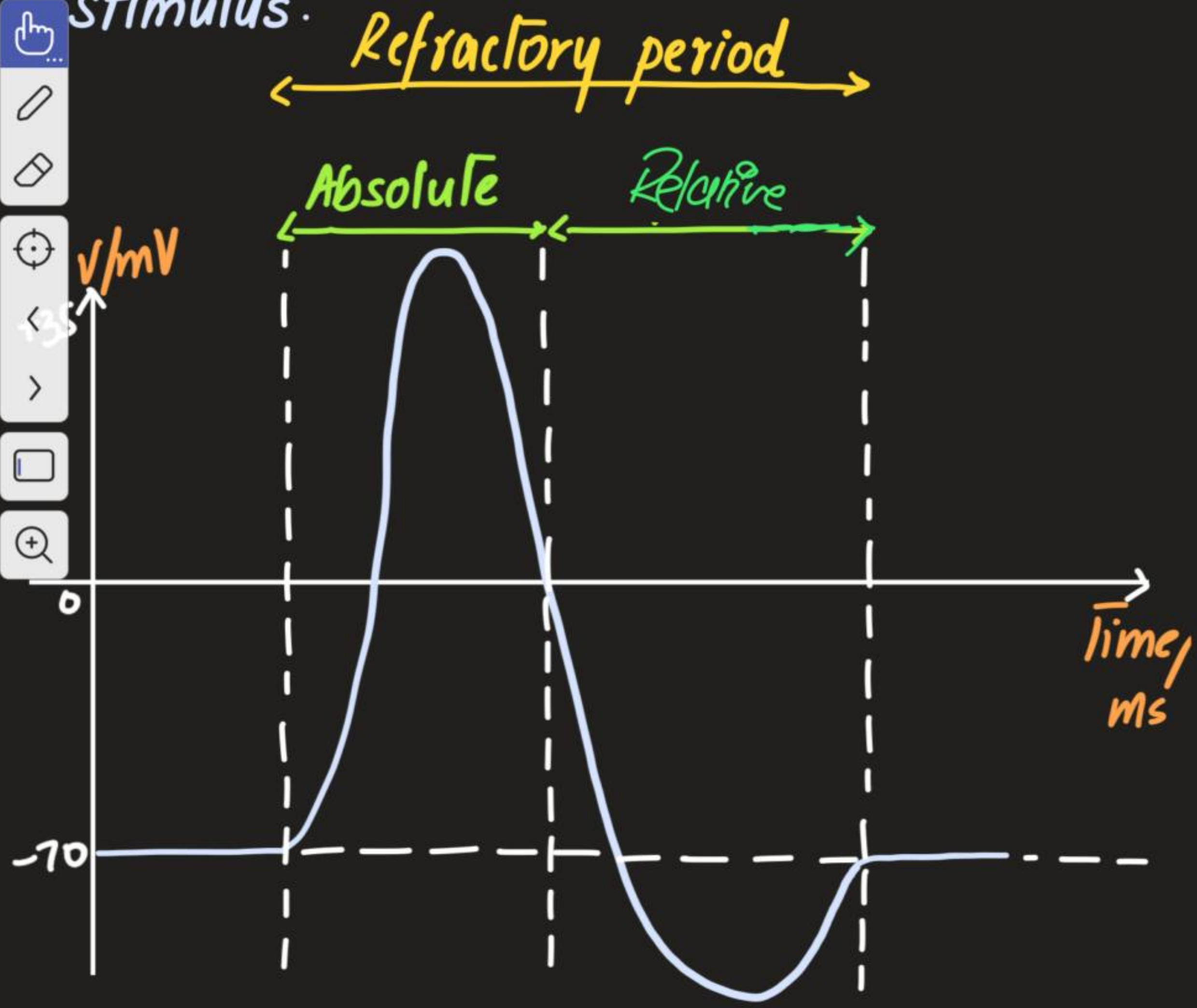
(B) Relative Refractory Period: during which a neuronal membrane can generate an AP with a suprathreshold stimulus.



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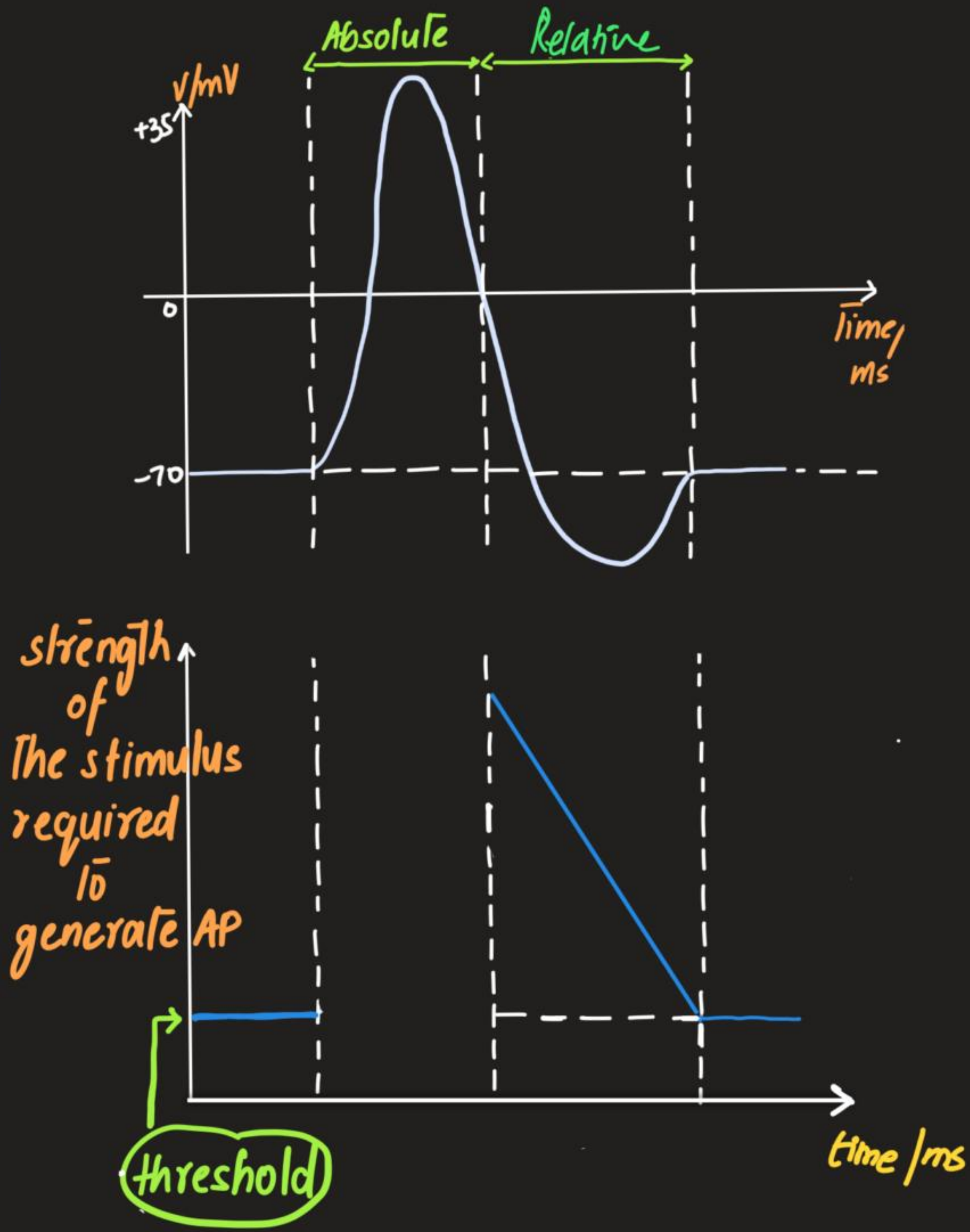
ACTION POTENTIAL AND REFRACTORY PERIOD



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* Significance of the refractory period includes:

(A) It determines the maximum frequency of impulses and therefore the speed of conduction.

(B) It ensures unidirectional flow of impulses.

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Factors affecting the speed of conduction

(A) Refractory period

* The longer the refractory period, the slower is the frequency of impulses.
* maximum frequency of action potentials

$$= \frac{1}{\text{refractory period}} \qquad \frac{1}{0.2\,ms} = \frac{1}{0.2\times10^{-3}}$$

(B) Axonal Diameter

* larger the diameter → the lesser is the resistance to the flow of ions across the axon → faster is the speed of conduction.

(C) Temperature

* ↑ temp → greater is the kinetic energy of ions → faster is the speed of conduction.
* extremely high temperatures lower the speed of conduction due to denaturation of membrane proteins.

(D) Myelin sheath

* **STRUCTURE**:
- Myelin is a form of lipid produced by Schwann cells.
- Myelin composition is:
  - 40% water
  - 60% dry mass
    - 80% lipids
    - 20% proteins

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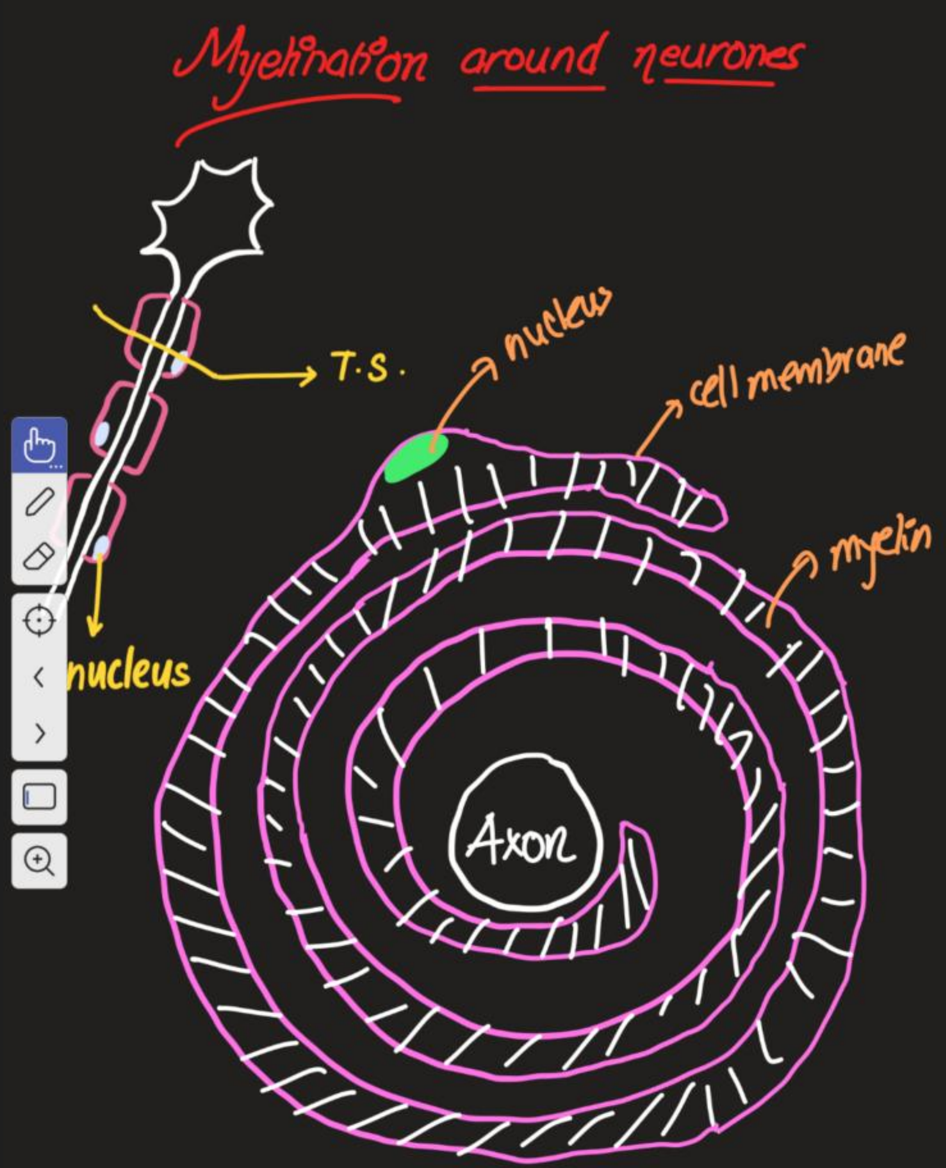
Control & Coordination



With
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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Review of factors affecting the speed of conduction
- Schwann cells, myelination & speed of conduction

Video Lecture 5 Slides

Mohammad Hussham Arshad, MD
Biology Department

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Nervous System:

* Classification
* Neurones → Structure and types
* Functions of the different parts of a neurone
* Spinal cord and the reflex arc
* Significance of reflex arc
* Resting membrane potential (RMP)
* Action potential
* Refractory period
* Factors affecting speed of conduction
  1) Refractory period 2) Axonal diameter
  3) Temperature 4) Myelination

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Factors affecting the speed of conduction

(A) Refractory period

* the longer the refractory period, the slower is the frequency of impulses.
* maximum frequency of action potentials

$$= \frac{1}{\text{refractory period}}$$

(B) Axonal Diameter

* larger the diameter → the lesser is the resistance to the flow of ions across the axon → faster is the speed of conduction.

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(C) Temperature

* ↑ temp → greater is the kinetic energy of ions → faster is the speed of conduction.
* extremely high temperatures lower the speed of conduction due to denaturation of membrane proteins.

(D) Myelin sheath

* STRUCTURE :
- Myelin is a form of lipid produced by Schwann cells.
- Myelin composition is :
  - → 40% water
  - → 60% dry mass
    - → 80% lipids
    - → 20% proteins

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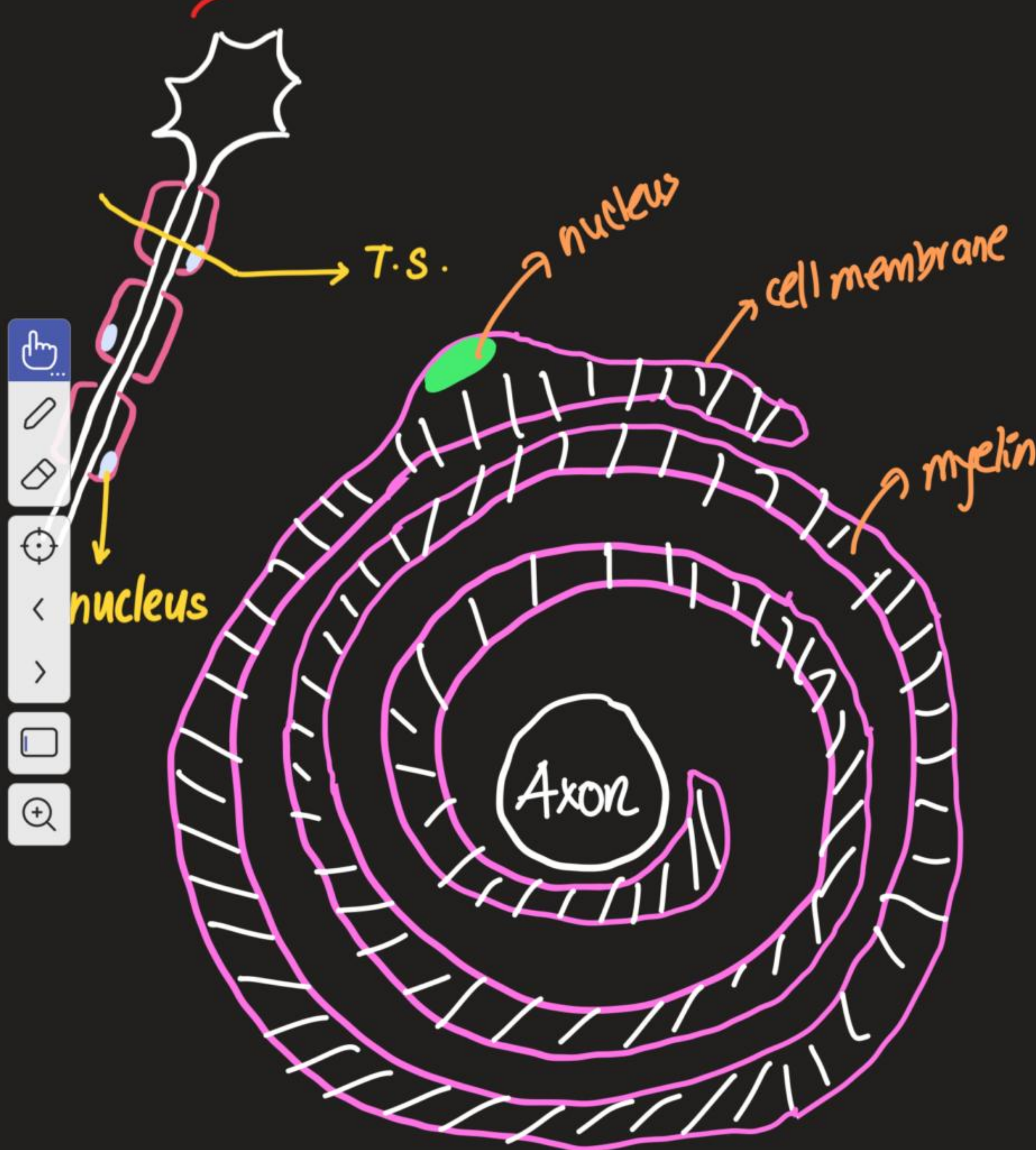
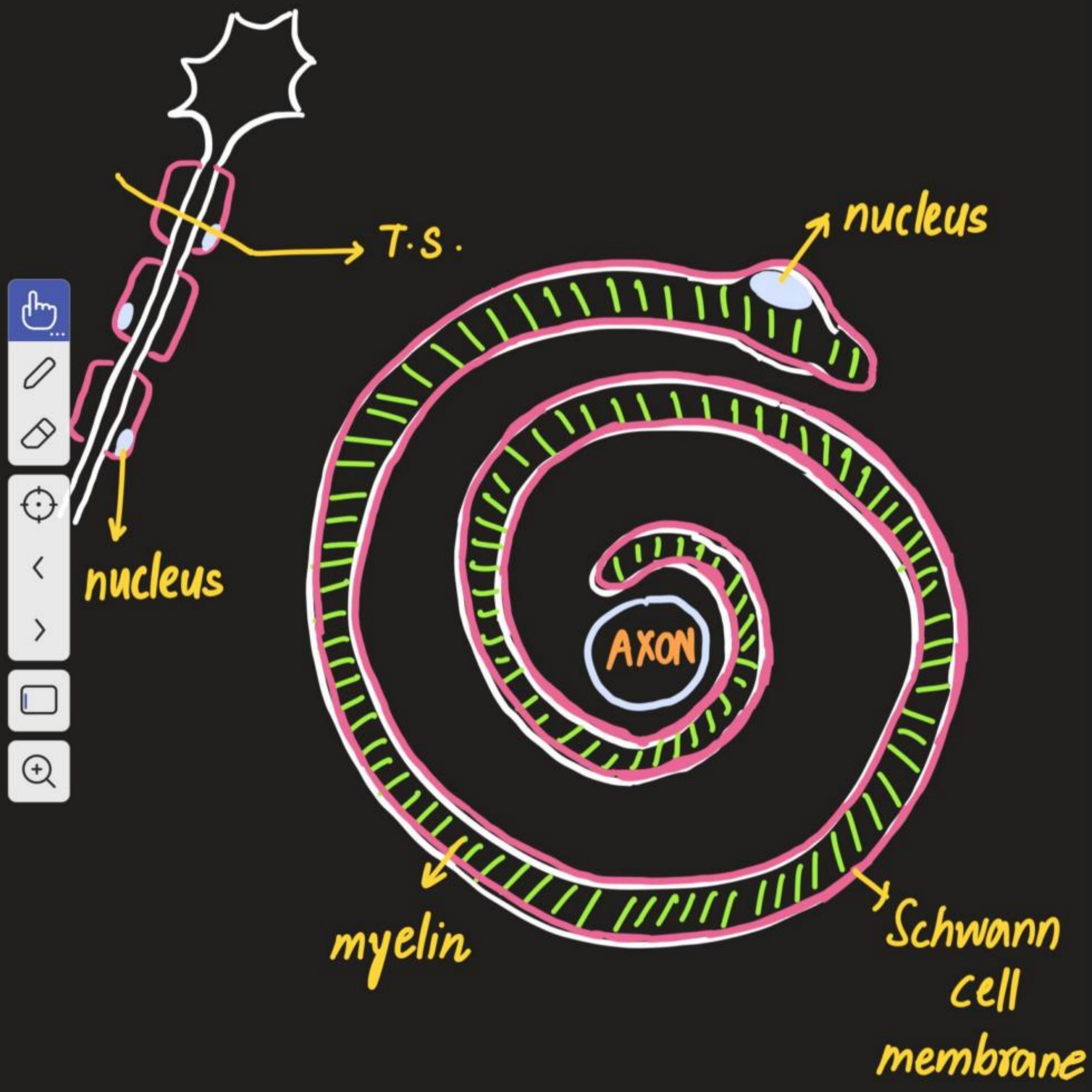
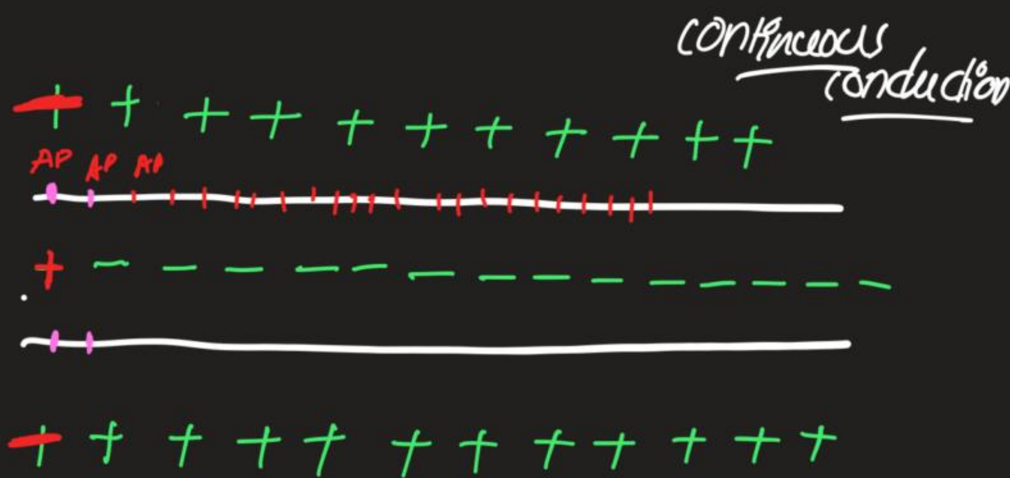
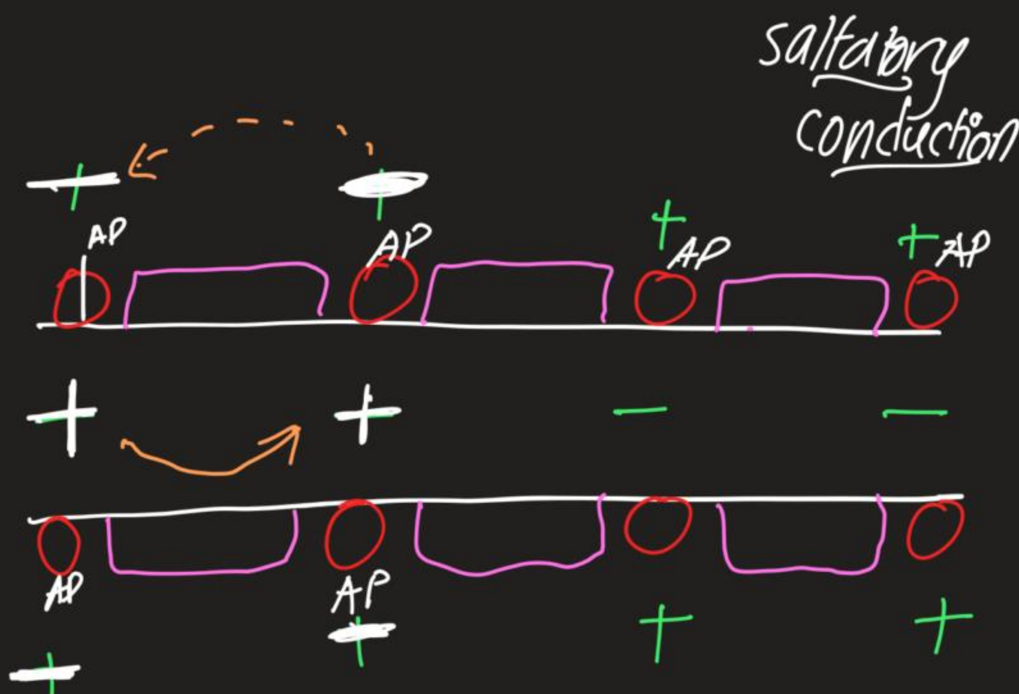
Myelination around neurones




T.S.
nucleus
nucleus
AXON
myelin
Schwann cell membrane

Myelination and speed of conduction





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Myelination and speed of conduction

* Myelin is a form of lipid produced by the Schwann cells.

* Schwann cells wrap around the neuronal membrane.

* Myelin sheath serves as an electrical insulator → preventing leakage of ions through the axonal membrane.

* Action potentials are ONLY generated at the nodes of Ranvier. APs jump from one node to another → a mechanism termed as saltatory conduction (saltare means to 'jump')

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* Local circuits develop between the nodes
* These local circuits are faster and passive.
* A myelinated neurone can conduct an electrical impulse at a speed of $100 ms^{-1}$
* An unmyelinated neurone transmits an electrical impulse at $0.5 ms^{-1}$

Q1: Outline how myelination affects the speed of conduction of an electrical impulse?


Questions

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Q1.

2 Fig. 2.1 shows the changes in membrane potential in an axon during the passage of a single impulse.

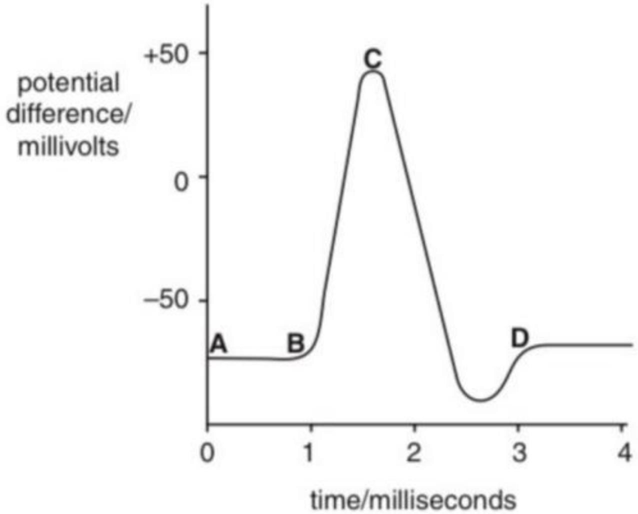

Fig. 2.1

(a) Outline how the resting potential from **A** to **B** is maintained.

* Na^+-K^+ pump transports $3Na^+$ outside and $2K^+$ into the neurone
* the leaky K^+ channels allow gradual loss of K^+
* this makes the inside of the neurone more negative than outside

[3]

(b) Describe how the changes in the membrane bring about depolarization from B to C.

* threshold stimulus leads to opening of voltage gated Na^+
* rapid entry of Na^+ into the axon
* this makes the inside more positive than outside

[3]

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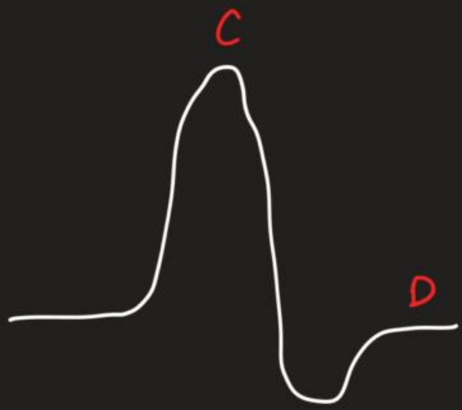

(c) Explain how the membrane is repolarised from C to D.

* the voltage gated Na^+ channels close at C and
* the voltage gated K^+ channels open
* K^+ rapidly leave the axon causing the membrane to repolarise

[3]

Q2.

(b) Fig. 8.1 shows the changes in potential difference (p.d.) across the membrane of a receptor cell over a period of time. The membrane was stimulated at time **A** and at time **B** with stimuli of different intensities.

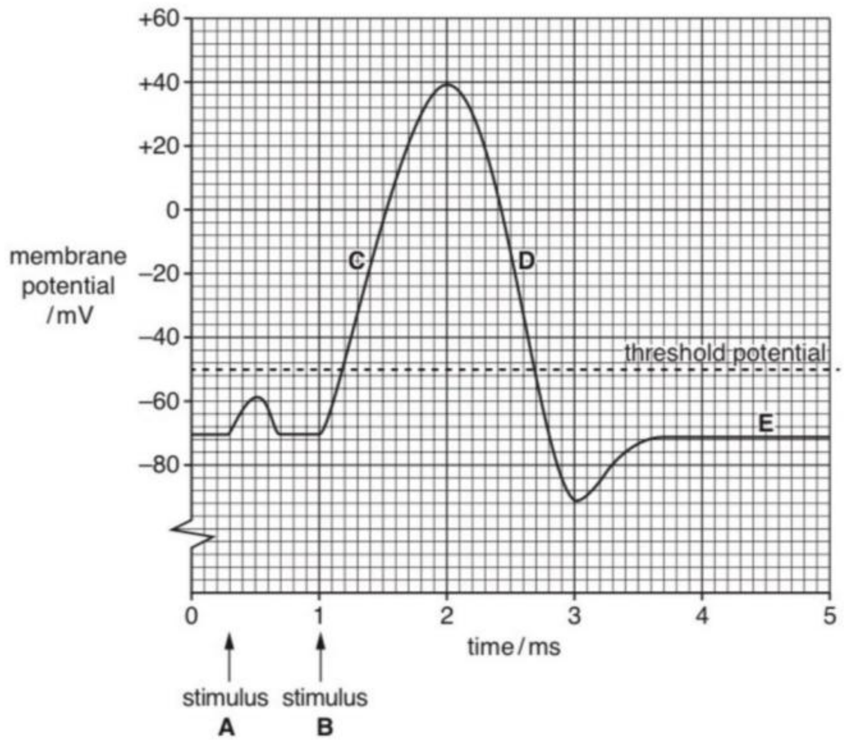

Fig. 8.1

(i) State which of the letters **C**, **D** and **E** on Fig. 8.1 correspond to each of these events. You may use each of the letters **C**, **D** or **E** once, more than once or not at all.

The Na^+/K^+ pump is operating ......C/D and E......

The voltage-gated Na^+ channels are open ......C......

The voltage-gated K^+ channels are open ......D......

[3]

Q3.

8 (a) Fig. 8.1 is a diagram of a sensory neurone and some receptor cells.

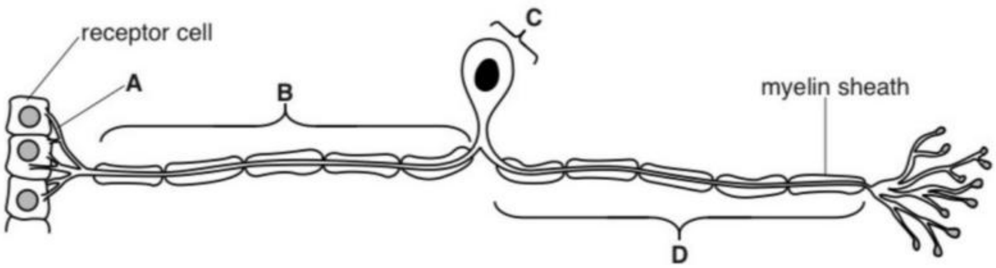

Fig. 8.1

Name the parts of the neurone labelled **A**, **B**, **C** and **D**.

A dendrites

B dendron

C cell body

D axon [4]

(b) Explain how the myelin sheath increases the speed of conduction of nerve impulses.

* myelin insulates the axon
* action potentials jump from one node to another → termed as saltatory conduction
* local circuits are setup between the nodes

[2]

(c) Fig. 8.2 shows the changes in the membrane potential of a sensory neurone when the receptor cells are stimulated.

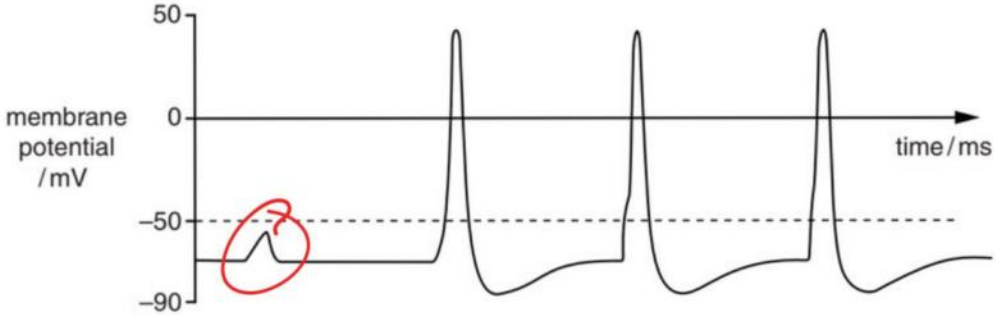

Fig. 8.2

Fig. 8.3 shows the strength of the stimuli applied to these receptor cells.

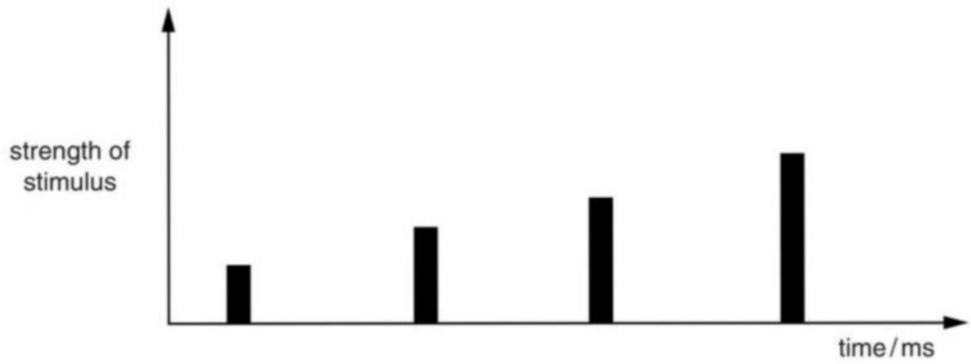

Fig. 8.3

With reference to Fig. 8.2 and Fig. 8.3, describe the relationship between the strength of the stimulus and the resulting action potential.

* subthreshold stimulus does NOT generate action potential
* action potential is an all or none phenomenon
* the shape of the action potential stays the irrespective of the strength of the stimulus

[2]

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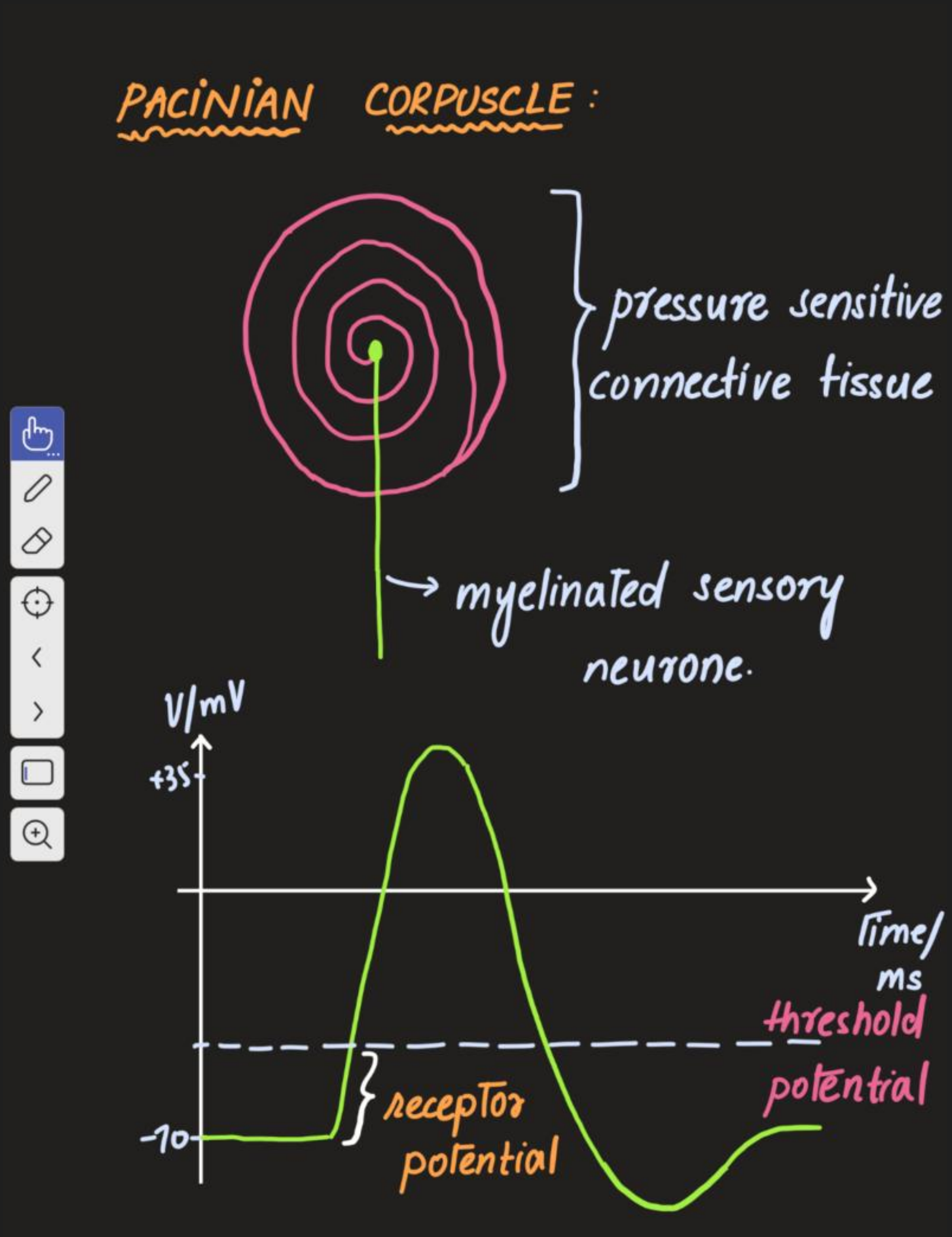
Control & Coordination



With

Mohammad Hussham Arshad, MD

ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Receptors & receptor potential
- Taste & chemoreceptors

Video Lecture 6 Slides

Mohammad Hussham Arshad, MD
Biology Department

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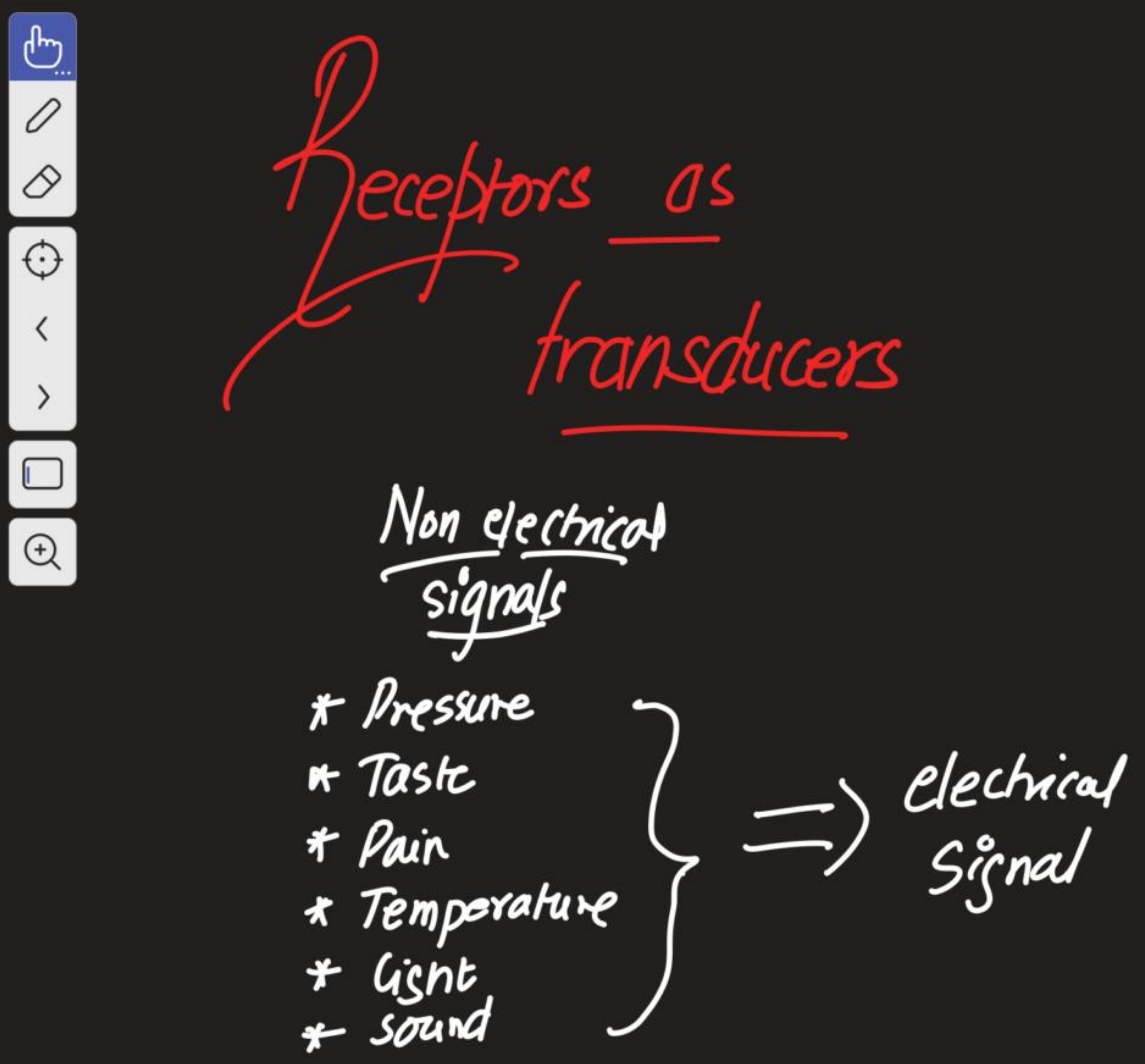
Nervous System:

* Classification
* Neurones → Structure and types
* Functions of the different parts of a neurone
* Spinal cord and the reflex arc
* Significance of reflex arc
* Resting membrane potential (RMP)
* Action potential
* Refractory period
* Factors affecting speed of conduction
  1) Refractory period 2) Axonal diameter
  3) Temperature 4) Myelination
* Myelination and saltatory conduction


Receptors as transducers
Non electrical signals
* Pressure
* Taste
* Pain
* Temperature
* Light
* Sound
⟹ electrical signal

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RECEPTORS

* Receptors are responsible for detecting non-electrical stimuli and converting it into an electrical signal.
* Receptors are therefore termed as transducers.
* A receptor can be a:

(A) specialised cell, or a

(B) sensory nerve ending

* Examples of receptors are:

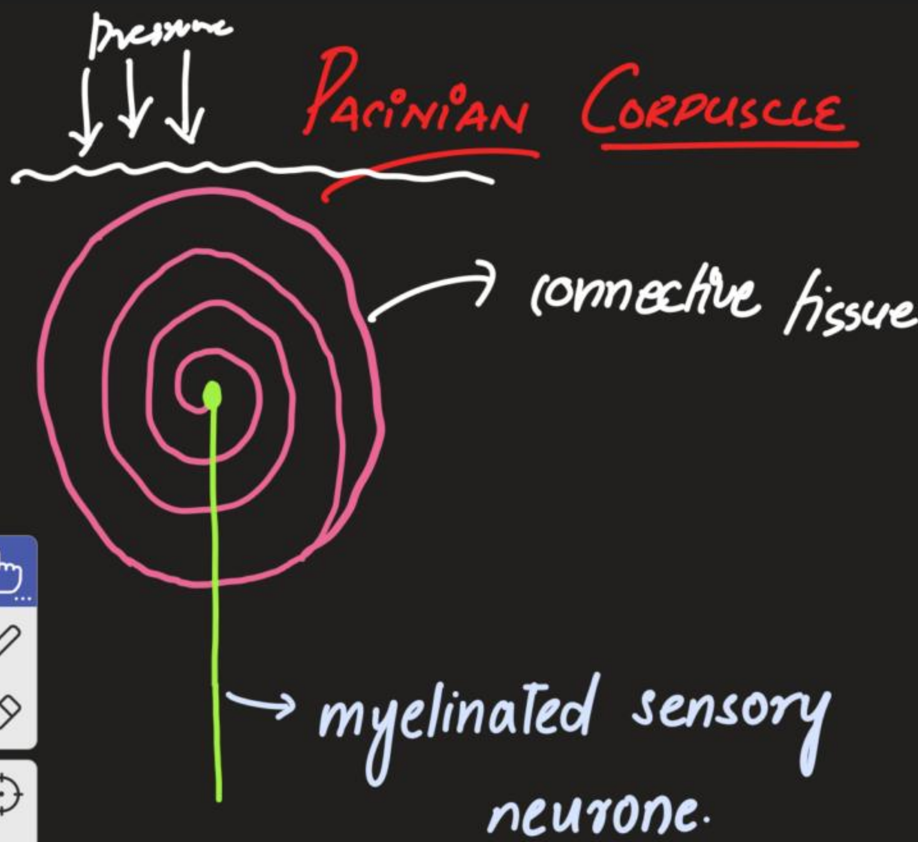
a) Pacinian corpuscle → pressure

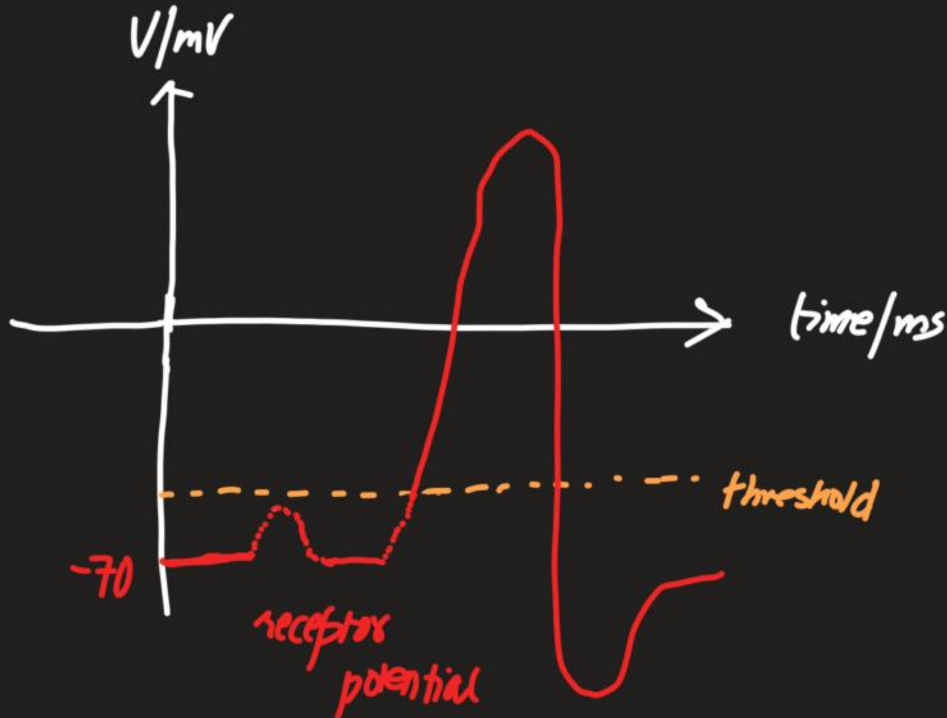
b) Chemoreceptors → taste

c) Meissner's corpuscle → touch

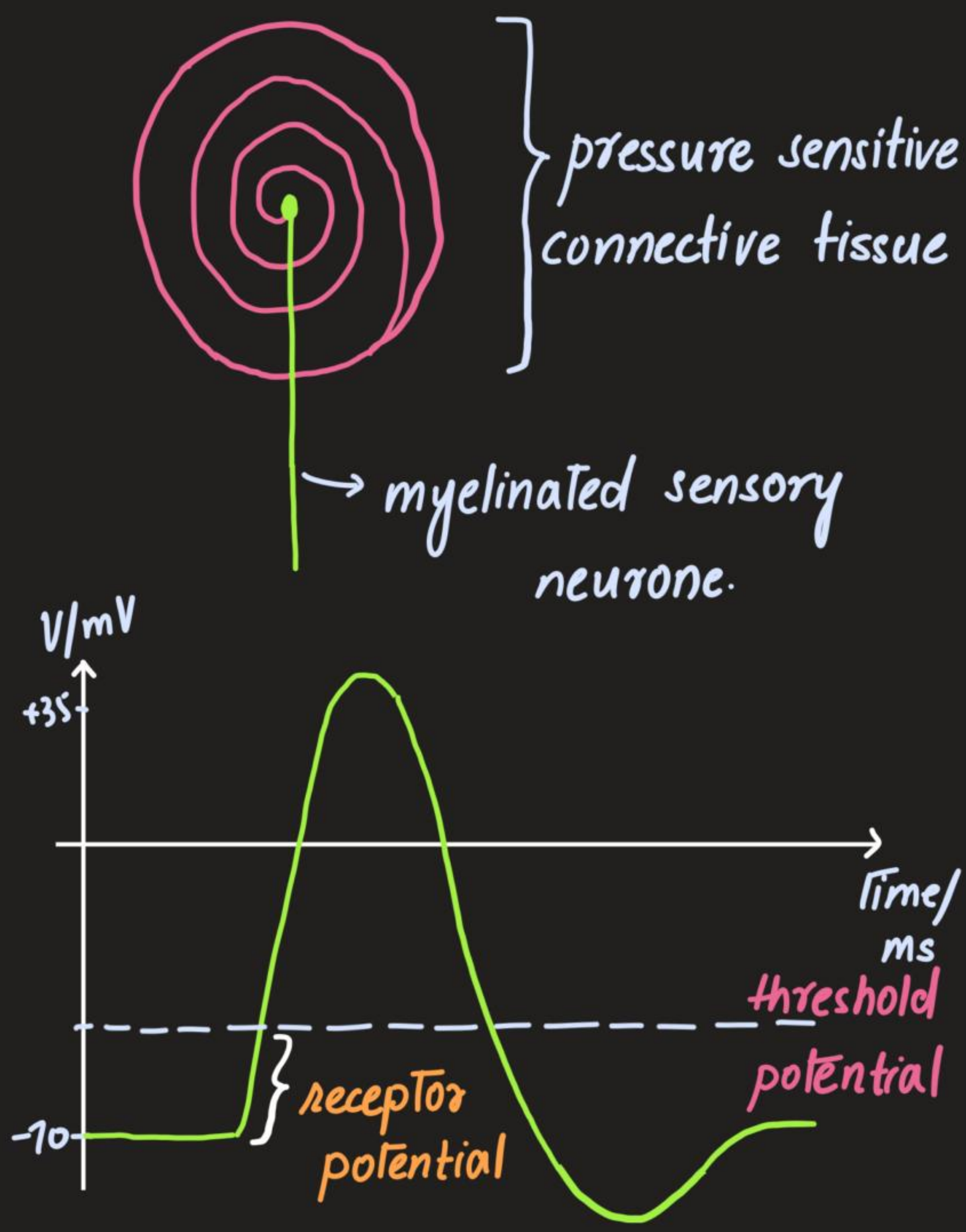
d) Thermoreceptors → temperature

e) Rods and cones → light


Pressure
Pacinian Corpuscle
connective tissue
myelinated sensory neurone.


V/mV
time/ms
threshold
-70
receptor potential

PACINIAN CORPUSCLE:



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Pressure Stimulus

↓

Deformation of the corpuscle

↓

Opens pressure sensitive Na^+ channels in the neuronal membrane

↓

Na^+ enter the neurone

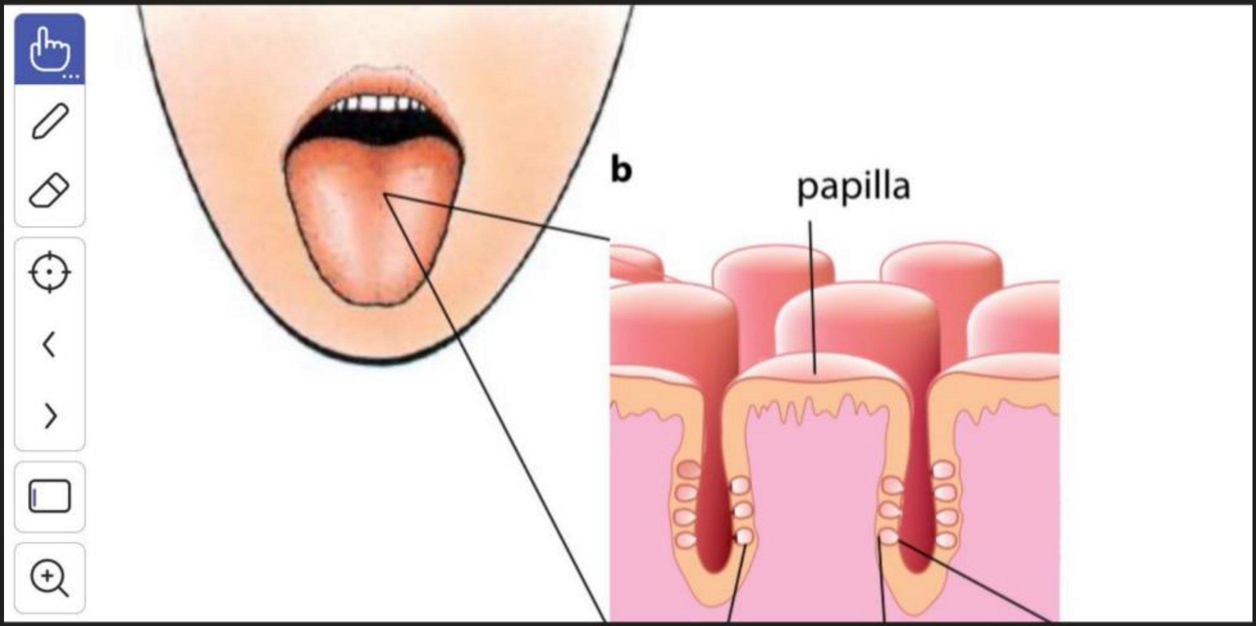
↓

Generates receptor (or generator) potential

↓

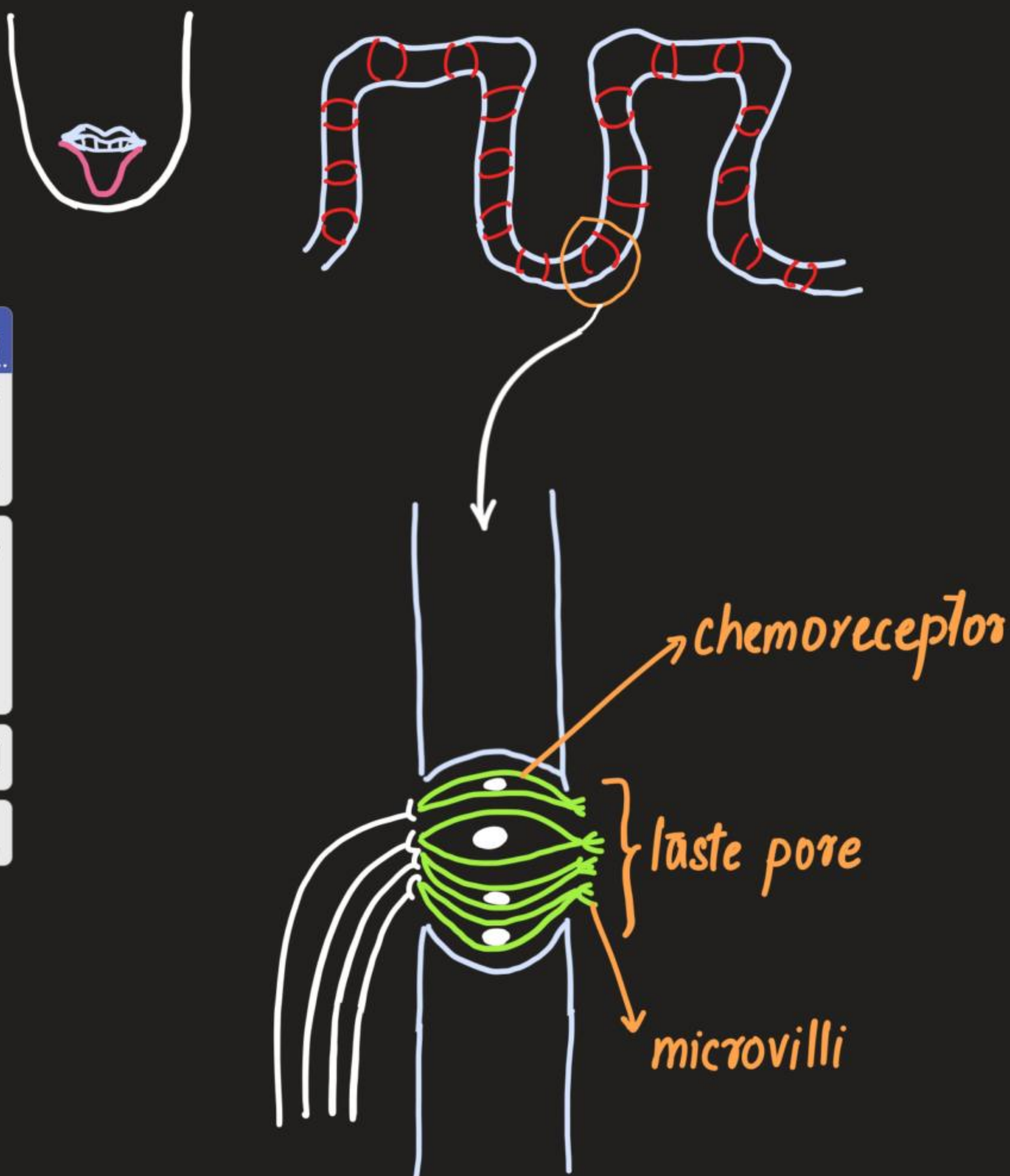
If receptor potential reaches threshold, an action potential is generated

TASTE & CHEMORECEPTORS



papillae → plural
papilla → singular

TASTE AND CHEMORECEPTORS



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* There are five distinguishable forms of taste:

(a) Sweet (b) Sour (c) Salty (d) Bitter

(e) Savory (umami)

* The surface of the tongue contains numerous papillae.

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* Each papilla consists of numerous taste buds.
* Around 50-100 chemoreceptor cells are present within each taste bud.
* Each chemoreceptor cell contains specialised protein receptors on its CSM, which enables it to detect the specific chemical stimulus. For example, there is a specific chemoreceptor cell which detects salty taste.

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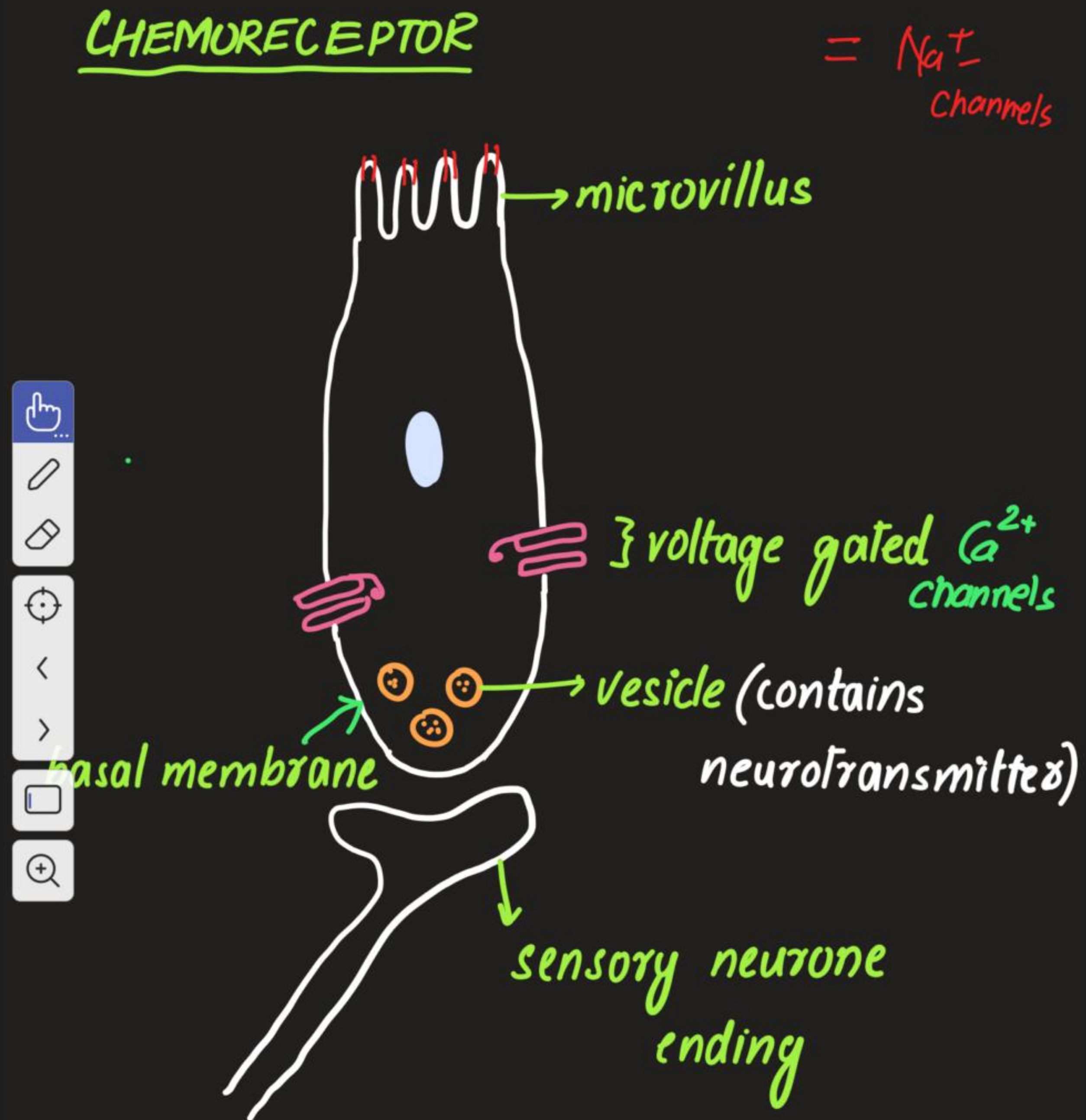
CHEMORECEPTOR



HEUSER

* Na^+ ions diffuse into the chemoreceptor cells through selective protein channels, present on the microvilli of the cells.

These microvilli provide a large surface area for the Na^+ ion channels.

* Entry of Na^+ ions depolarises the chemoreceptor cells to generate a receptor potential.

* Depolarisation stimulates the opening of voltage-gated Calcium channels which allow Ca^{2+} ions to diffuse into the chemoreceptor.

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* High conc. of Ca^{2+} ions causes vesicles containing the neurotransmitter to fuse with the CSM, releasing the neurotransmitter via exocytosis.

* The neurotransmitter diffuses across the synaptic cleft to bind to its receptors on the cell membrane of a sensory nerve ending.

* The sensory neurone transmits the impulse to the central nervous system.

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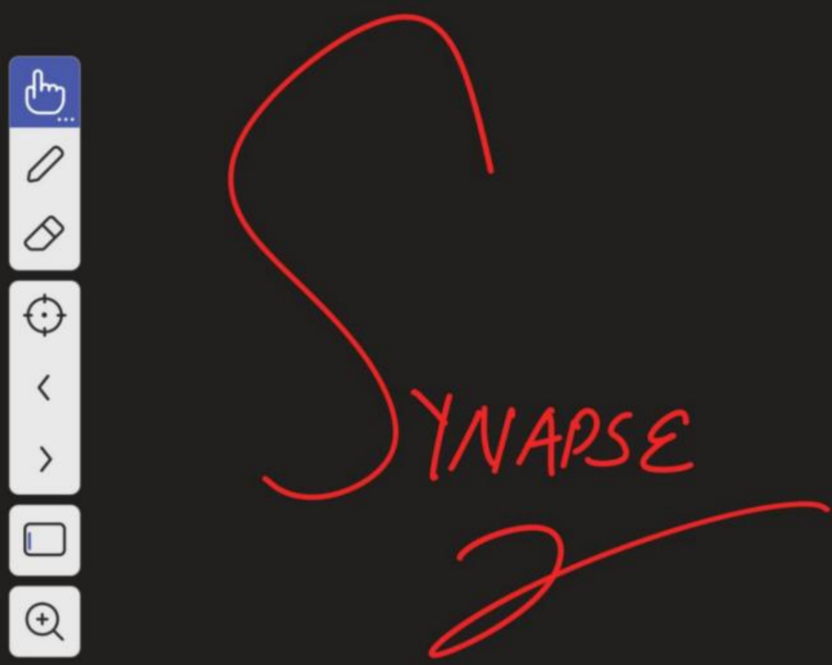
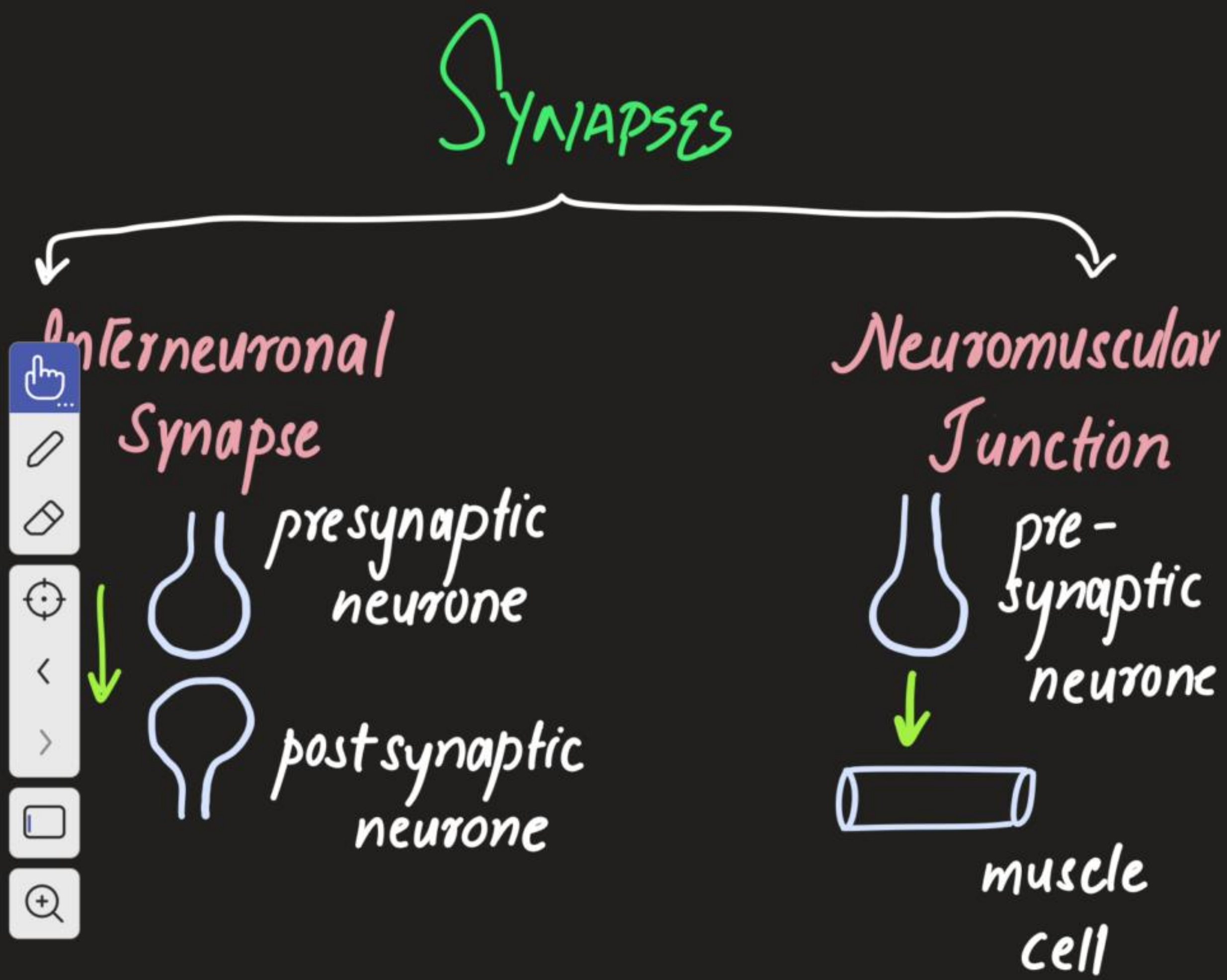
Q : Describe using named examples, how sensory receptors in mammals generate action potentials. [6]

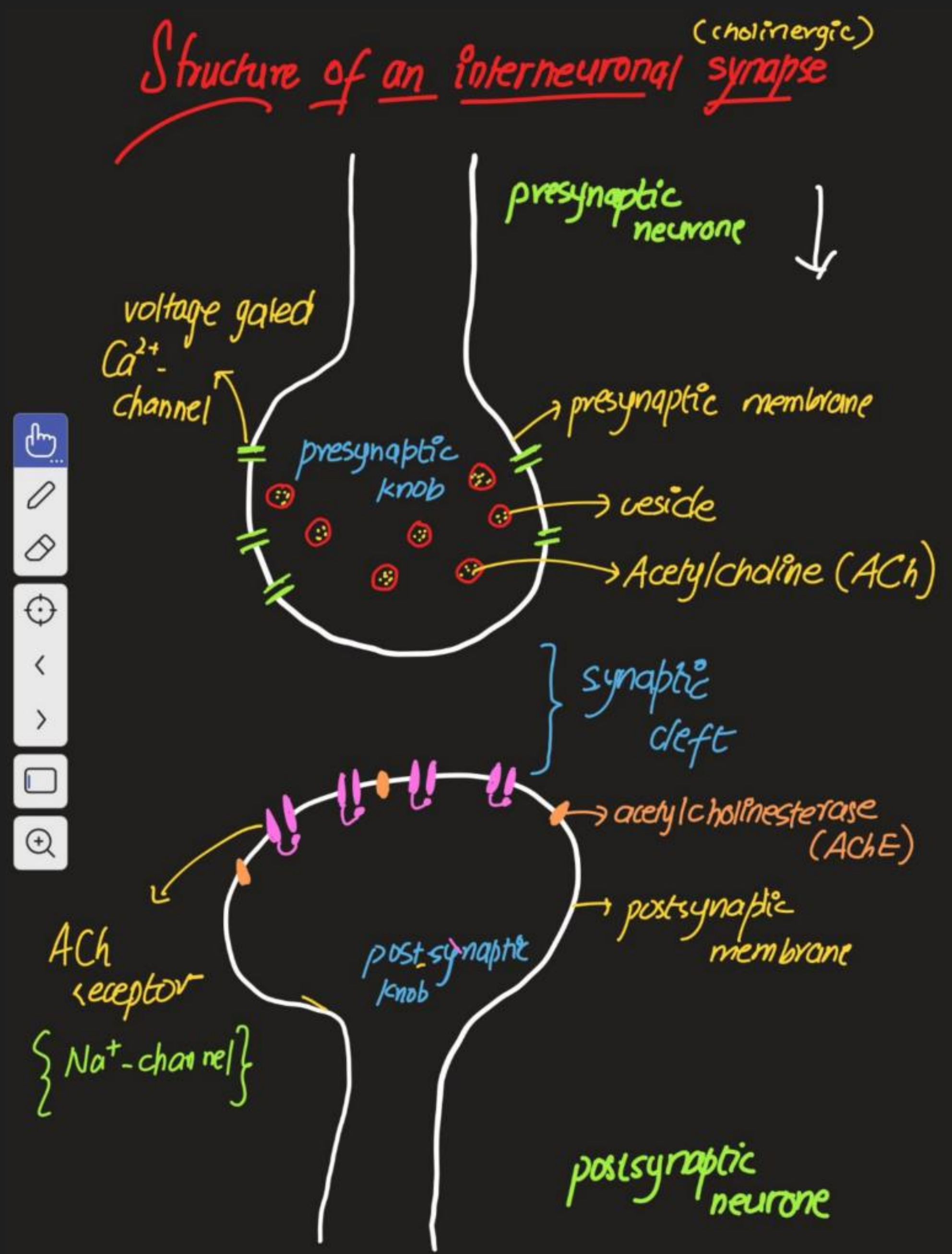
Ans: Receptors are specialised cells or sensory nerve endings responsible for converting non electrical stimuli into an action potential. They are therefore termed as energy transducers. For e.g, Pacinian corpuscles in the skin convert mechanical stimulus (pressure) into an action potential. Similarly, rods and cones in the retina transduce light energy into an action potential.

For pacinian corpuscle, pressure stimulus opens specific Na^+ ion channels on the receptor membrane leading to inward movement of Na^+ ions. This generates a receptor potential. If the receptor potential reaches the threshold, an action potential is generated. Greater the strength of the stimulus, greater is the frequency of action potentials generated.


SYNAPSE


Synapses
Interneuronal Synapse
presynaptic neurone
postsynaptic neurone
Neuromuscular Junction
pre-synaptic neurone
muscle cell

Control & Coordination



With

Mohammad Hussham Arshad, MD

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ADVANCED LEVEL BIOLOGY 9700
UNIT 15: Control & Coordination

Learning Objectives:

- Synapse: Structure & Functions
- Comparison of hormonal & nervous system

Video Lecture 7 Slides

Mohammad Hussham Arshad, MD
Biology Department

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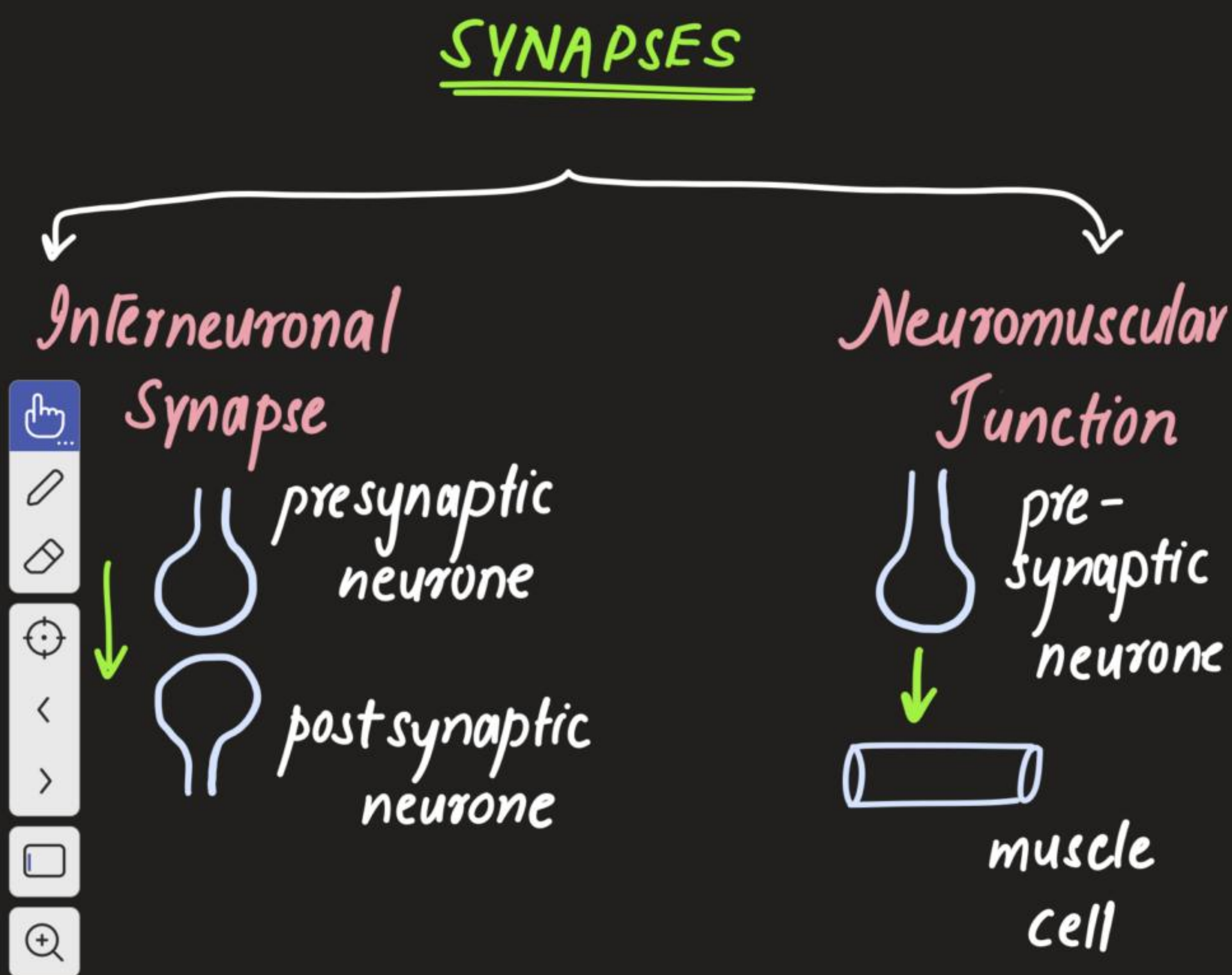
Nervous System:

* Classification
* Neurones → Structure and types
* Functions of the different parts of a neurone
* Spinal cord and the reflex arc
* Significance of reflex arc
* Resting membrane potential (RMP)
* Action potential
* Refractory period
* Factors affecting speed of conduction
    1) Refractory period 2) Axonal diameter
    3) Temperature 4) Myelination
* Receptors as transducers


SYNAPSES
Interneuronal Synapse
presynaptic neurone
postsynaptic neurone
Neuromuscular Junction
pre-synaptic neurone
muscle cell

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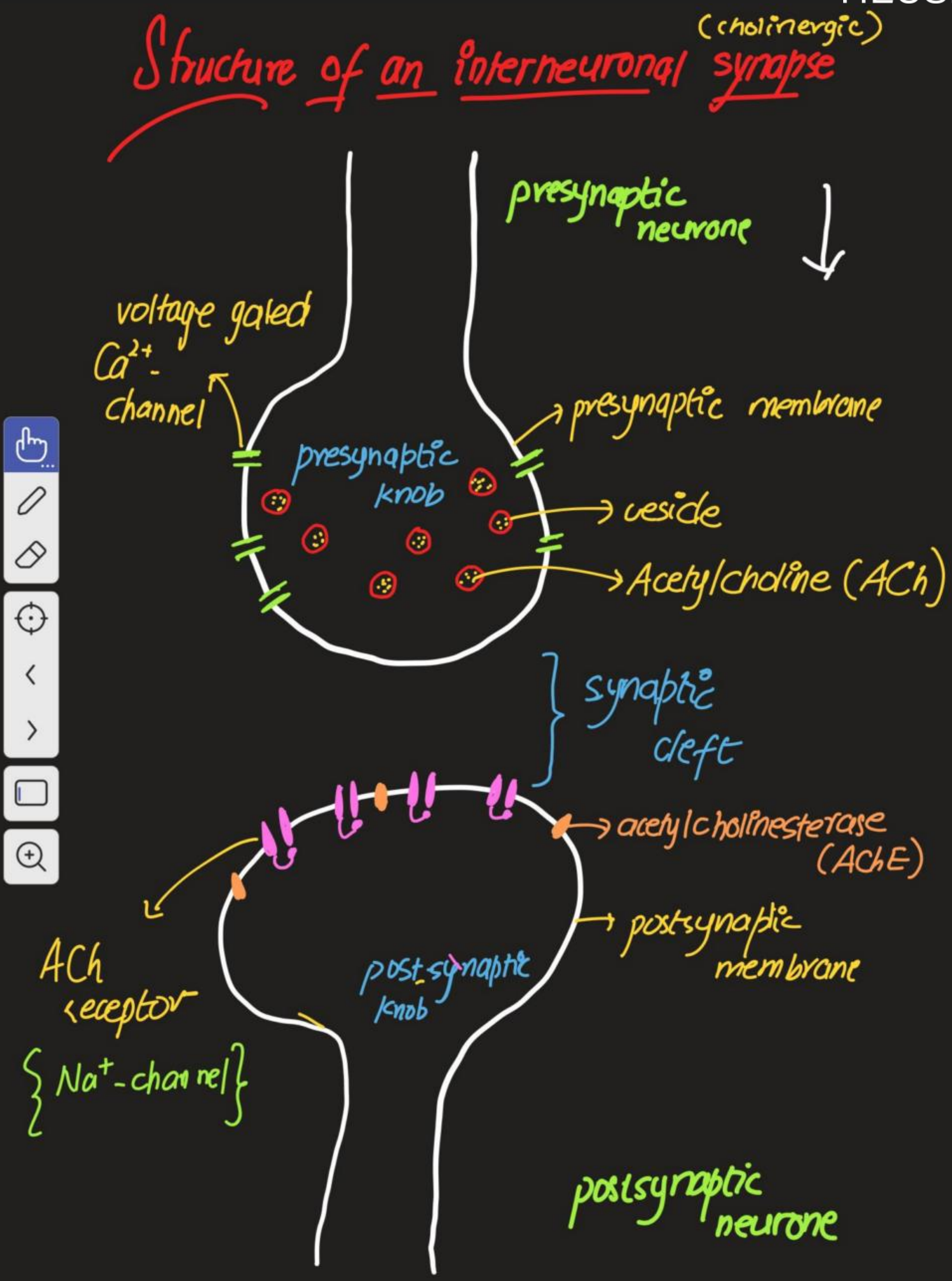
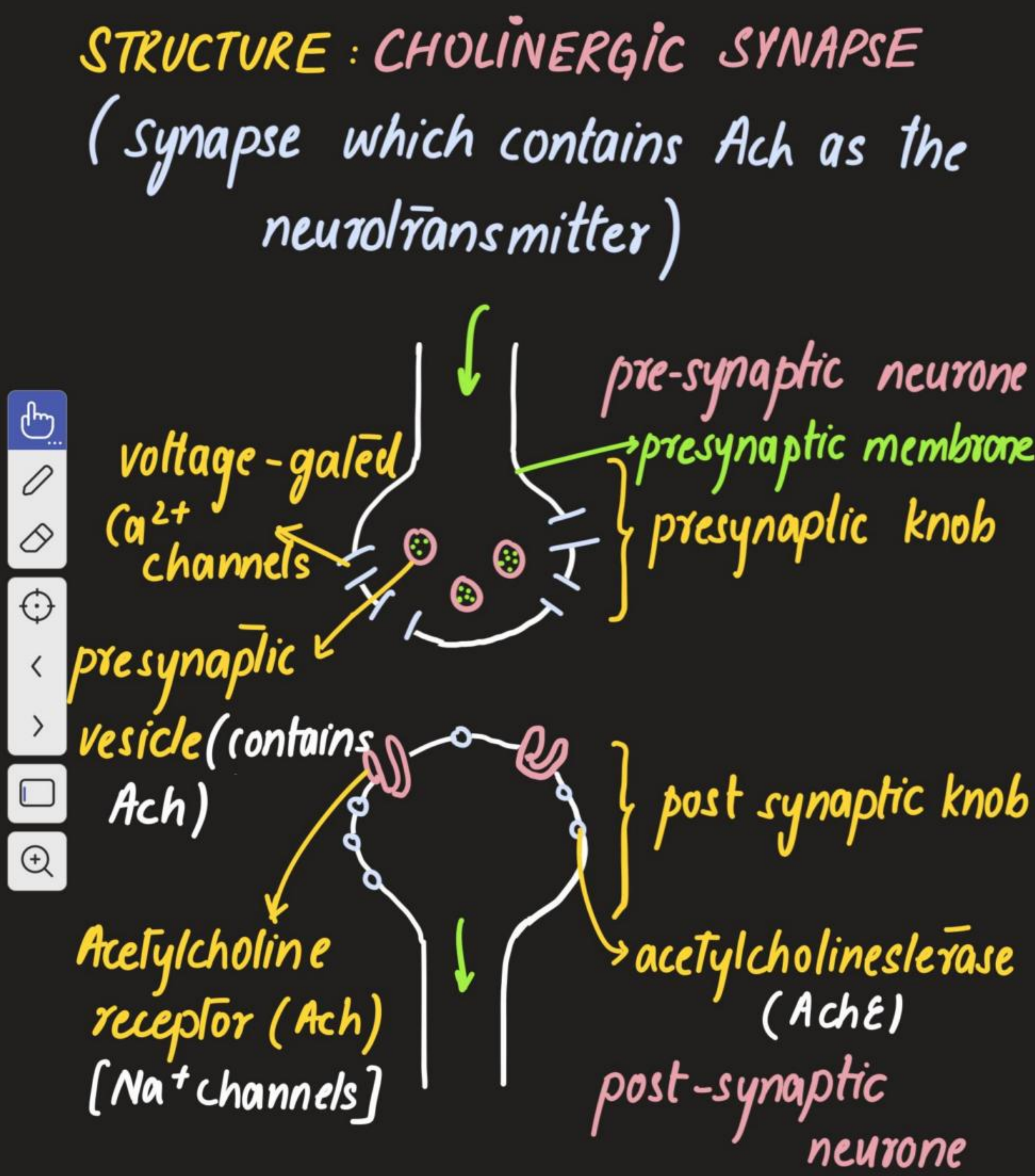

Structure of an interneuronal synapse
(cholinergic)
presynaptic neurone
voltage gated Ca^{2+}-channel
presynaptic membrane
presynaptic knob
vesicle
Acetylcholine (ACh)
synaptic cleft
acetylcholinesterase (AChE)
postsynaptic membrane
ACh receptor
{Na^+-channel}
post-synaptic knob
postsynaptic neurone


STRUCTURE : CHOLINERGIC SYNAPSE
(Synapse which contains Ach as the neurotransmitter)
pre-synaptic neurone
presynaptic membrane
presynaptic knob
voltage-gated Ca2+ channels
presynaptic vesicle (contains Ach)
post synaptic knob
Acetylcholine receptor (Ach) [Na+ channels]
acetylcholinesterase (AchE)
post-synaptic neurone

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Defining a synapse....

* A synapse is a functional apposition between neurones where an impulse is transmitted from a presynaptic neurone to post-synaptic neurone via chemical means (neuro transmitter).
* The synapse mentioned above is an interneuronal synapse.

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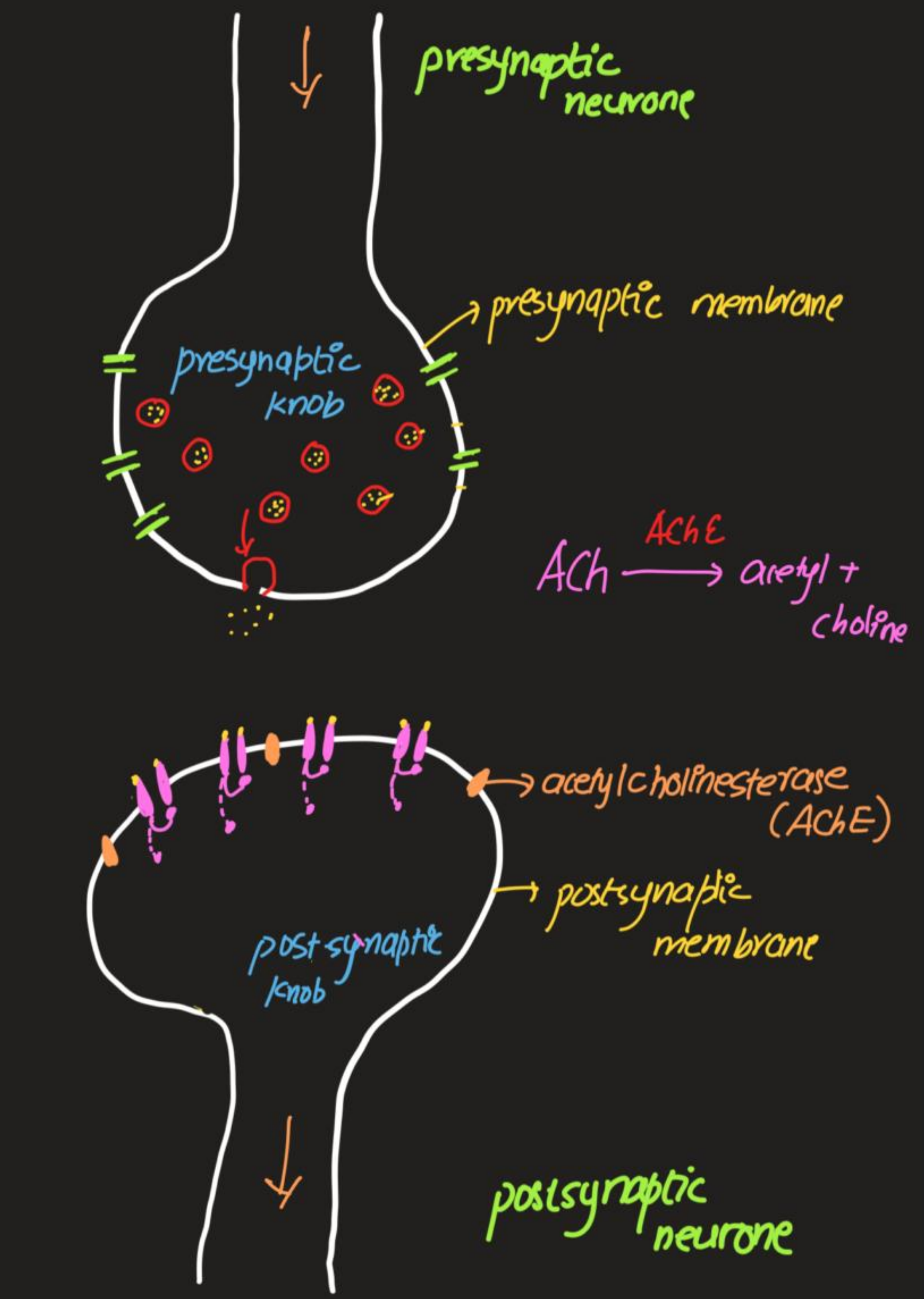
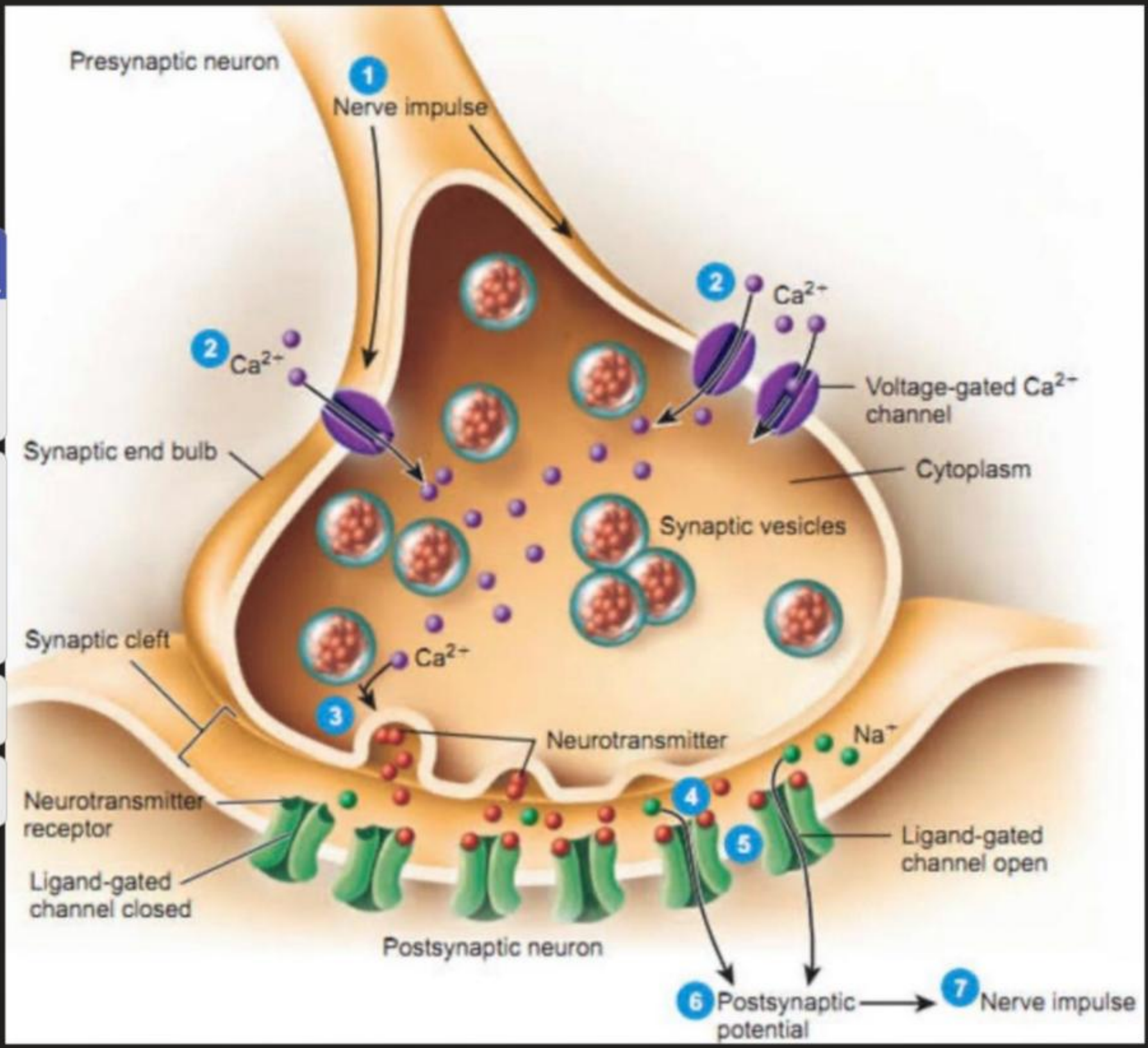
How does a synapse function?




Presynaptic neuron
1 Nerve impulse
2 Ca2+
2 Ca2+
Voltage-gated Ca2+ channel
Synaptic end bulb
Cytoplasm
Synaptic vesicles
Synaptic cleft
Ca2+
3
Neurotransmitter
Na+
4
Neurotransmitter receptor
5
Ligand-gated channel open
Ligand-gated channel closed
Postsynaptic neuron
6 Postsynaptic potential
7 Nerve impulse

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How does a synapse function?

An action potential arrives at the presynaptic membrane

↓

Depolarises the presynaptic membrane

↓

Opens voltage-gated Ca^{2+} channels.

↓

Ca^{2+} influx into the presynaptic knob

↓

Vesicles containing Ach fuse with the pre-synaptic membrane

↓

Ach released via exocytosis

↓

Ach diffuses across the synaptic cleft

↓

Ach binds to its receptors on the post-synaptic membrane

↓

Ach receptors open enabling Na^+ influx

↓

Depolarisation of the post-synaptic membrane

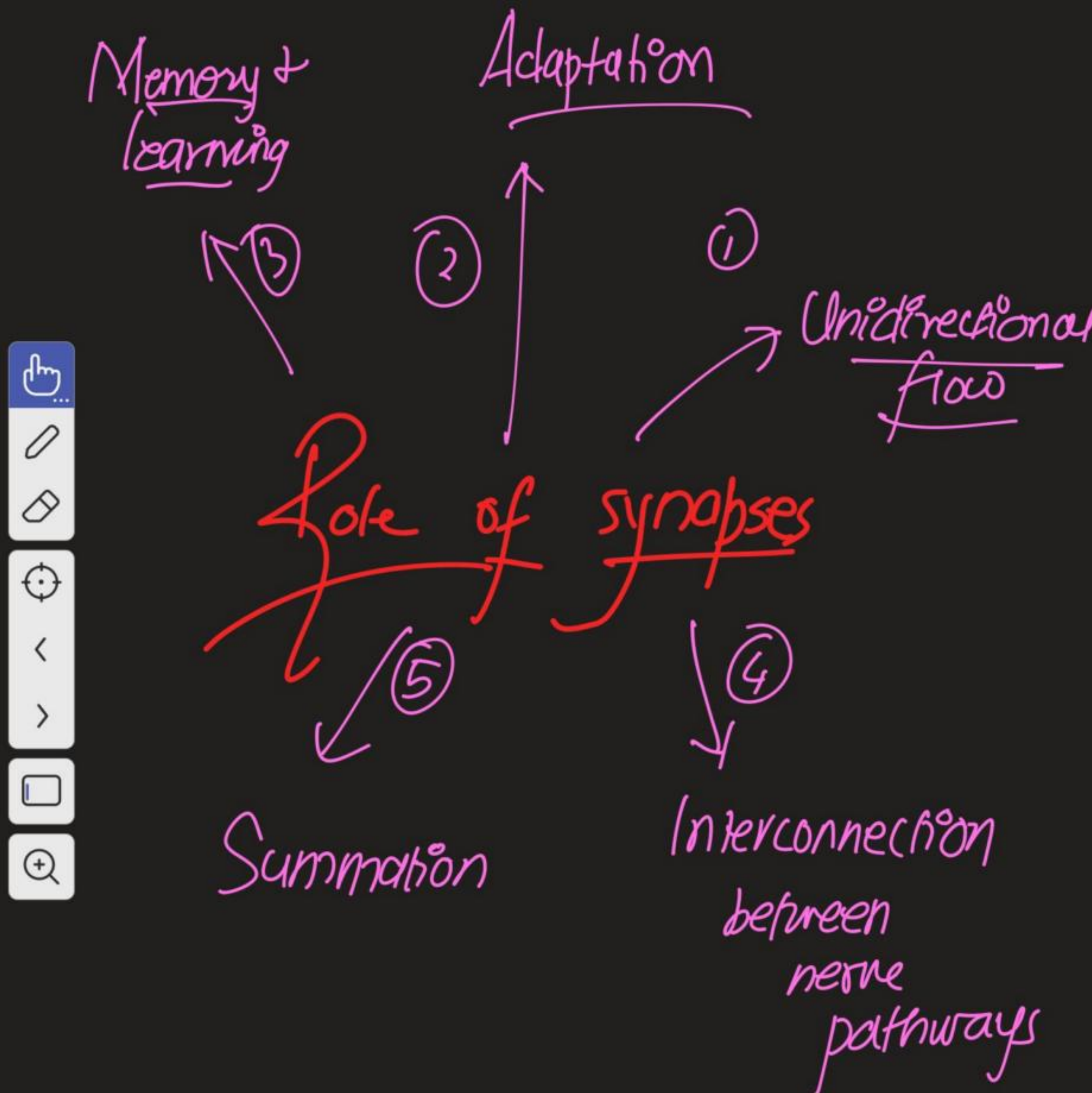
* How is Ach removed from the synaptic cleft?

(a) AchE breaks down Ach.

$$\text{Ach} \xrightarrow{\text{AchE}} \text{Acetate} + \text{choline}$$

(b) reuptake of choline into the presynaptic neurone.

(c) Ach diffuses away from the synaptic cleft.


Role of synapses
① Unidirectional flow
② Adaptation
③ Memory & learning
④ Interconnection between nerve pathways
⑤ Summation

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Roles of Synapses

(A) Unidirectional flow of impulses

Synapse ensures unidirectional flow of impulses. The presence of (1) presynaptic vesicles in the presynaptic knob, (2) voltage-gated Ca^{2+} channels on the presynaptic membrane and (3) acetylcholine receptors on the post-synaptic membrane ensure that impulses always travel from the presynaptic neurone towards the post-synaptic neurone.

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(B) Adaptation

Synapses have the ability to adapt. Adaptation refers to the reduction in the frequency of the action potentials over time along a neurone in response to a constant stimulus. This prevents the nervous system from receiving unnecessary information at all times.

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(C) Memory and Learning

Synapses are important in the process of memory and learning. There are trillions of synapses in the brain. New information is absorbed through a process characterised by changes in synaptic inter-connections among neurones in the hippocampus and the cerebral cortex, regions of the brain associated with memory.

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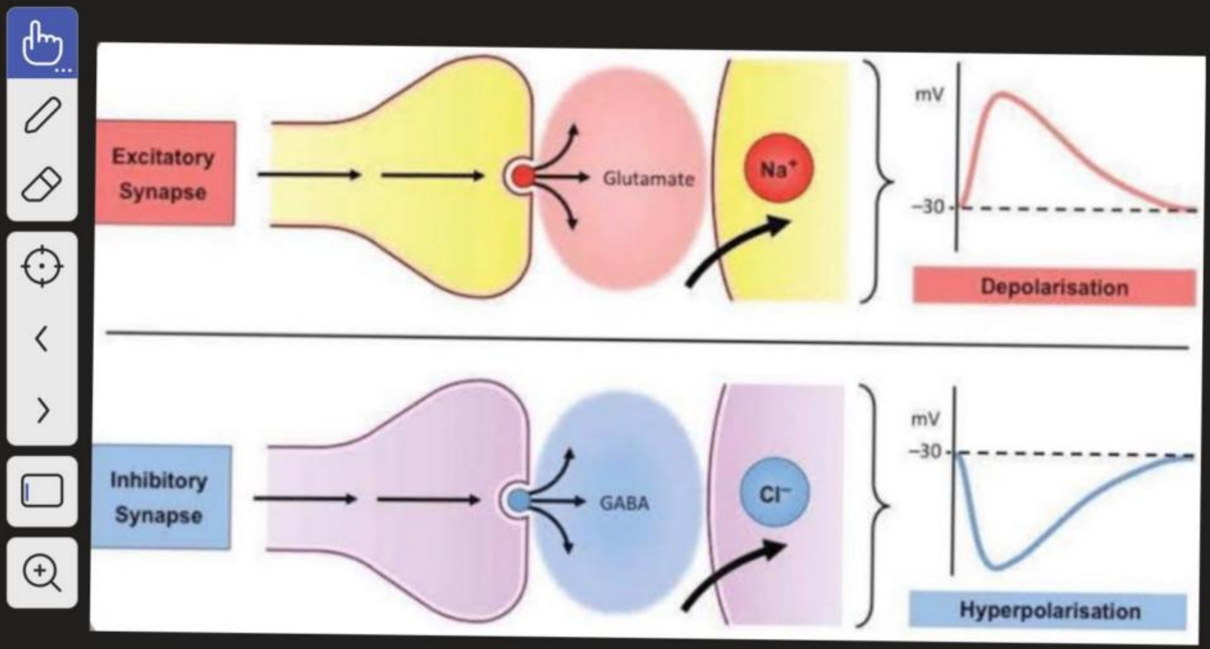
(D) Interconnection between nerve pathways

One neurone can have many synapses relating to it thus allowing interconnection of numerous nerve pathways. This increases the range of responses which can occur due to a particular stimulus. It also allows more information to be collected. Excitatory and inhibitory synapses also allow a wider range of behaviour.


Excitatory Synapse
Glutamate
Na+
mV
−30
Depolarisation
Inhibitory Synapse
GABA
Cl−
mV
−30
Hyperpolarisation

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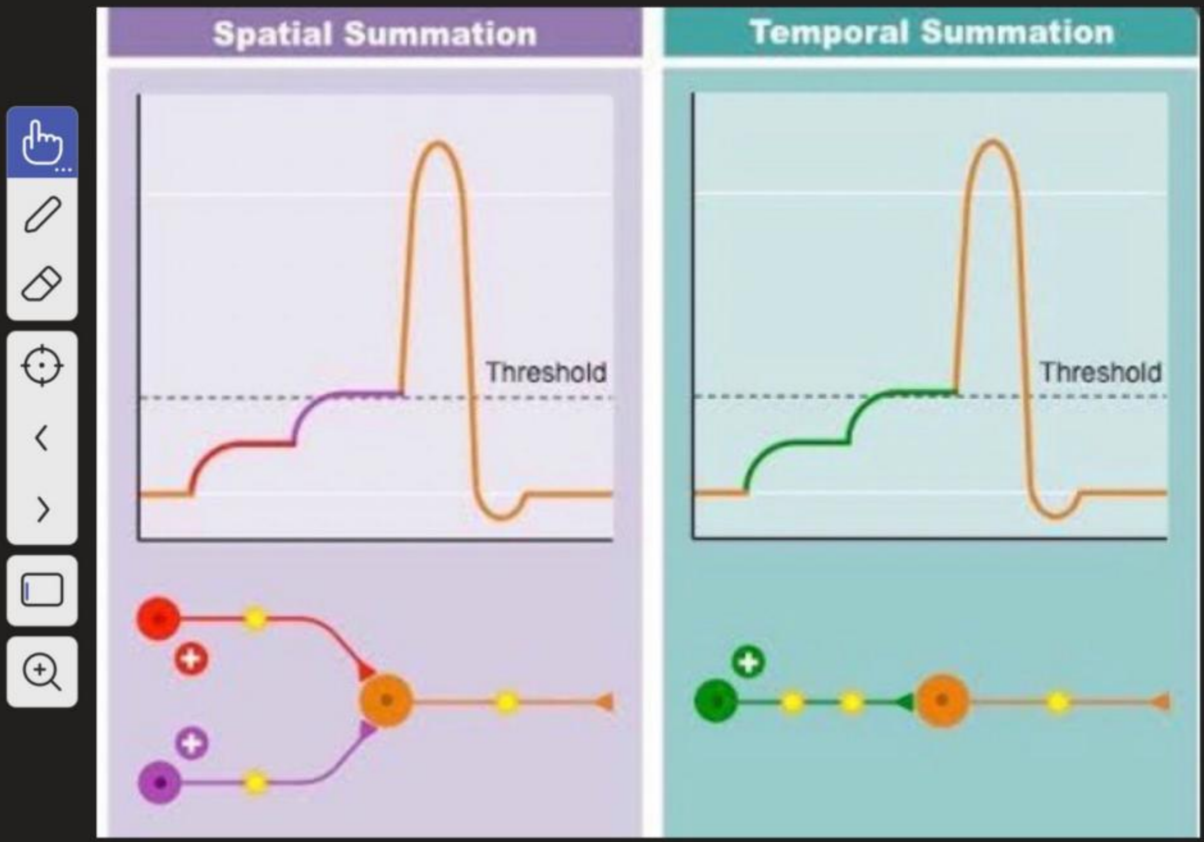
(E) Summation

Low frequency impulses that do not produce enough neuro-transmitter to trigger a new action potential in the post-synaptic neurone, can be made to do so by a process called summation. This needs a build-up of neurotransmitter in the synapse by one of the two methods:


Spatial Summation
Temporal Summation
Threshold
Threshold

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spatial summation → where a number of different presynaptic neurones together release enough neurotransmitter to trigger a new action potential.

Temporal summation → where a single presynaptic neurone releases neurotransmitter many times over a short period. If the total amount of neurotransmitter exceeds the threshold value of the post-synaptic neurone, then a new action potential is triggered.

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Q1: Describe how an electrical impulse crosses a cholinergic synapse? [9]

Ans: A nerve impulse crosses a cholinergic synapse via chemical means using the neurotransmitter Acetylcholine.
An action potential arrives at the pre-synaptic membrane which causes opening of voltage-gated Ca^{2+} channels. Ca^{2+} enter the presynaptic knob enabling vesicles to fuse with the presynaptic membrane releasing acetylcholine via exocytosis.

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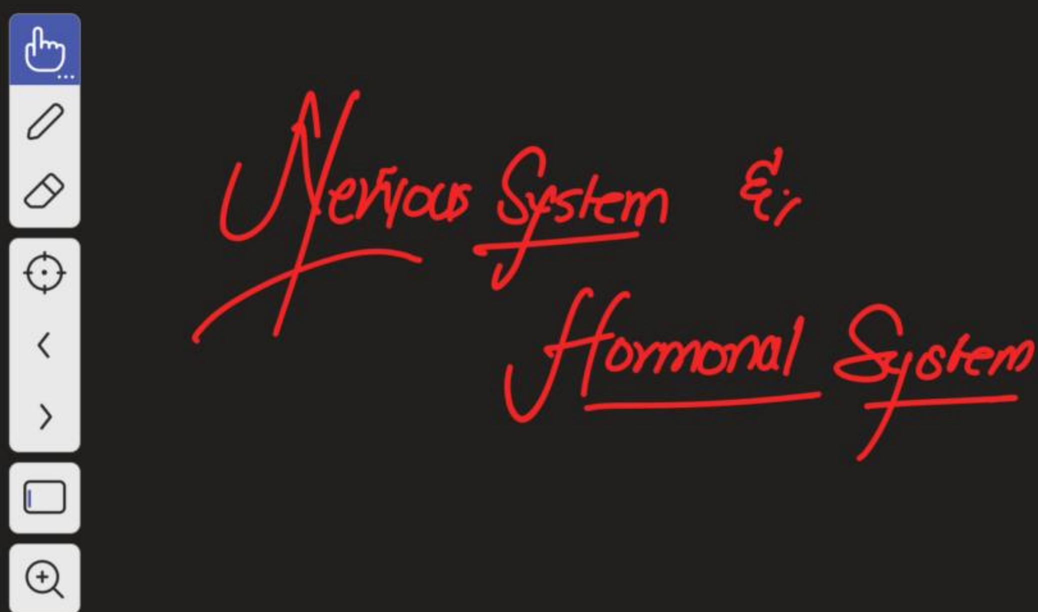
Acetylcholine diffuses across the synaptic cleft and binds to its receptors in the postsynaptic membrane. Ach receptors are Na^+-channels. Binding of Ach opens these channels allowing Na^+ to enter the post-synaptic knob thereby depolarising the post-synaptic membrane. Ach is removed from the cleft by the action of acetylcholinesterases — enzymes which hydrolyse Ach to form acetate and choline.

Q2: Describe how a synapse functions? [9]

Q3: Outline the roles of synapses in the nervous system? [8]


Nervous System &
Hormonal System

Q4: Describe the differences b/w hormonal and nervous system?

Hormonal System	Nervous System
→ Hormonal system is a chemical form of communication.	→ Nervous system involves electrical impulses.
→ Hormones are released into the blood stream to travel to their target sites.	→ The electrical impulses are carried by neurones
→ Hormonal responses are slow.	→ Neural responses are rapid.

→ The hormones are released by the endocrine glands and travel to their target sites which are more widespread.	→ The electrical impulses generated travel to more localized sites.
→ The effect is long-lasting.	→ The effect is for a brief period

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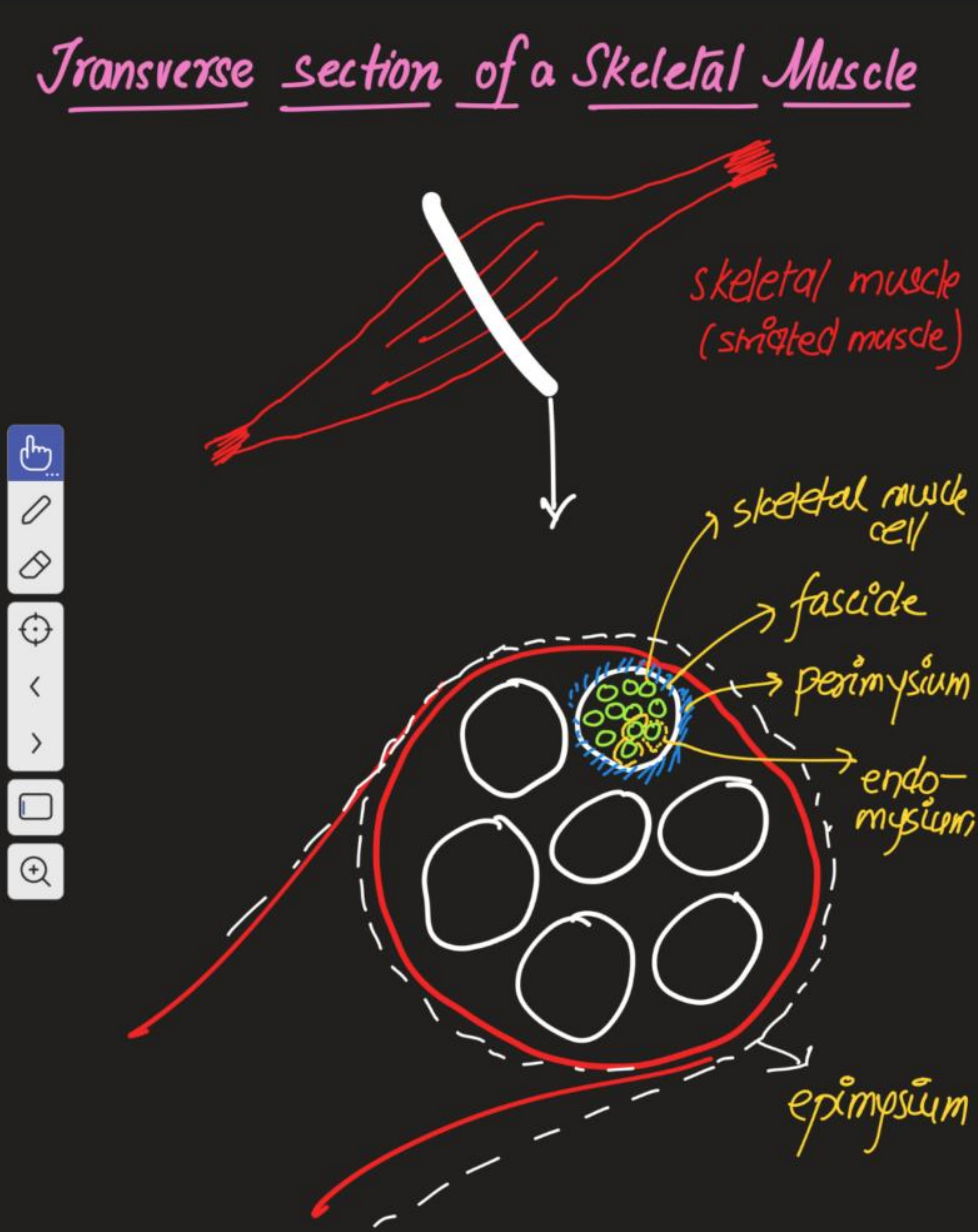
Control & Coordination



With

Mohammad Hussham Arshad, MD

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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Skeletal Muscle Structure 1

Video Lecture 8 Slides

Mohammad Hussham Arshad, MD
Biology Department

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Control and Coordination

* Nervous system
* Skeletal muscle structure, neuromascular junction and muscle contraction
* Female reproductive system
* Plant Growth Regulators
    - Auxins
    - Gibberellins

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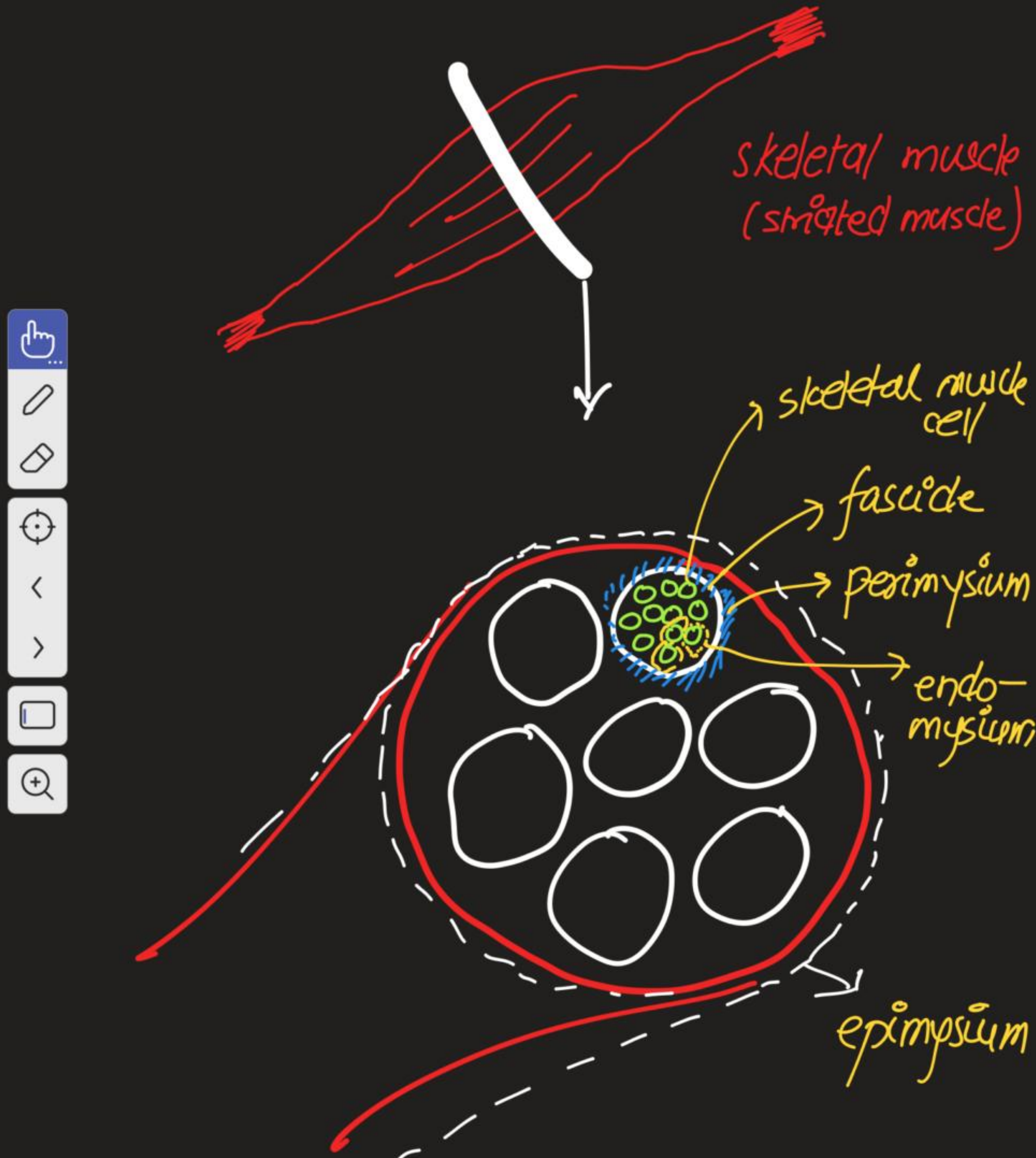
Transverse section of a Skeletal Muscle



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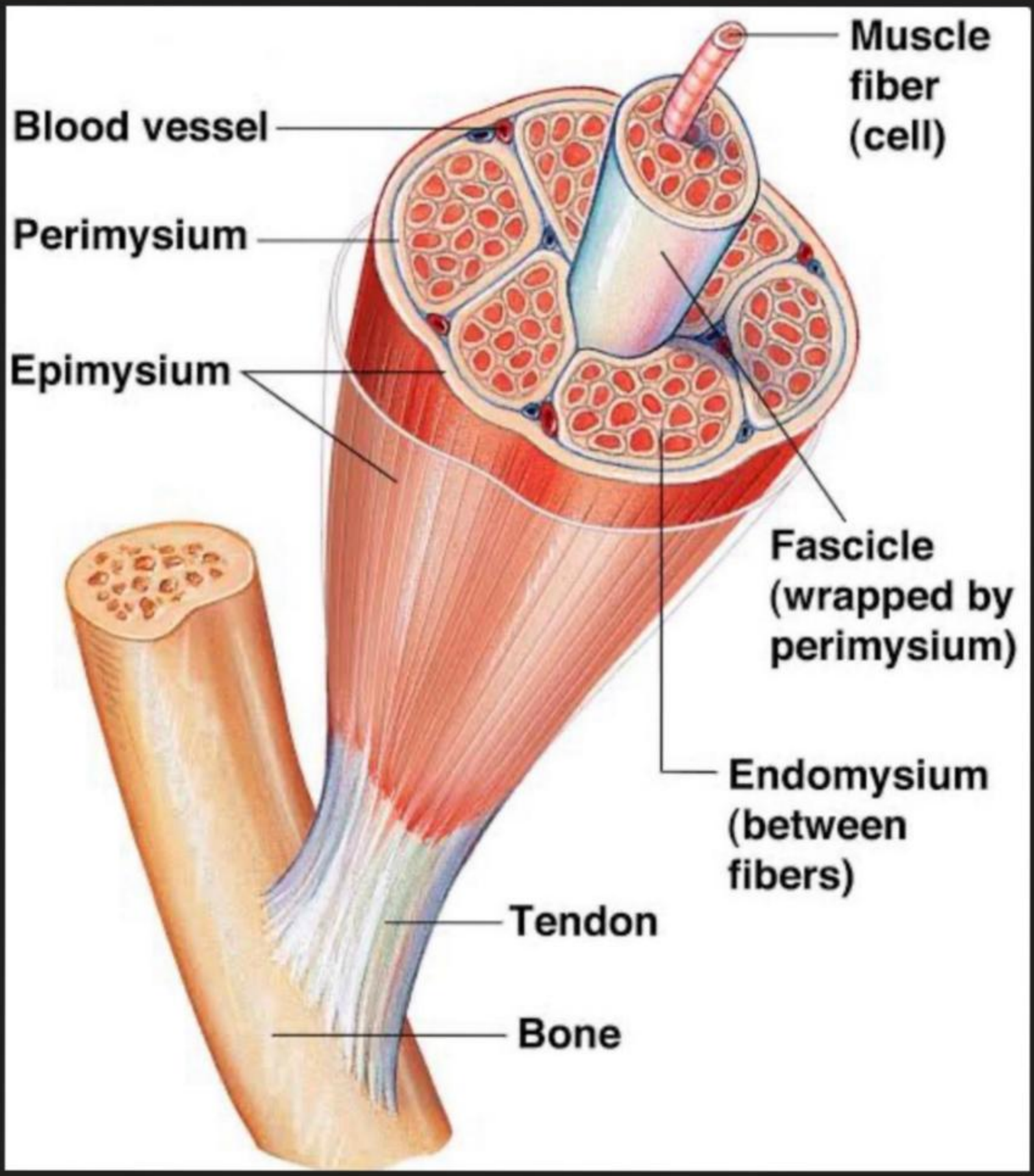
Skeletal muscle structure



tissue known as the endomysium.

(6) Each fascicle is surrounded by a layer of connective tissue known as the perimysium.

(7) The entire skeletal muscle is surrounded by connective tissue known as the epimysium.

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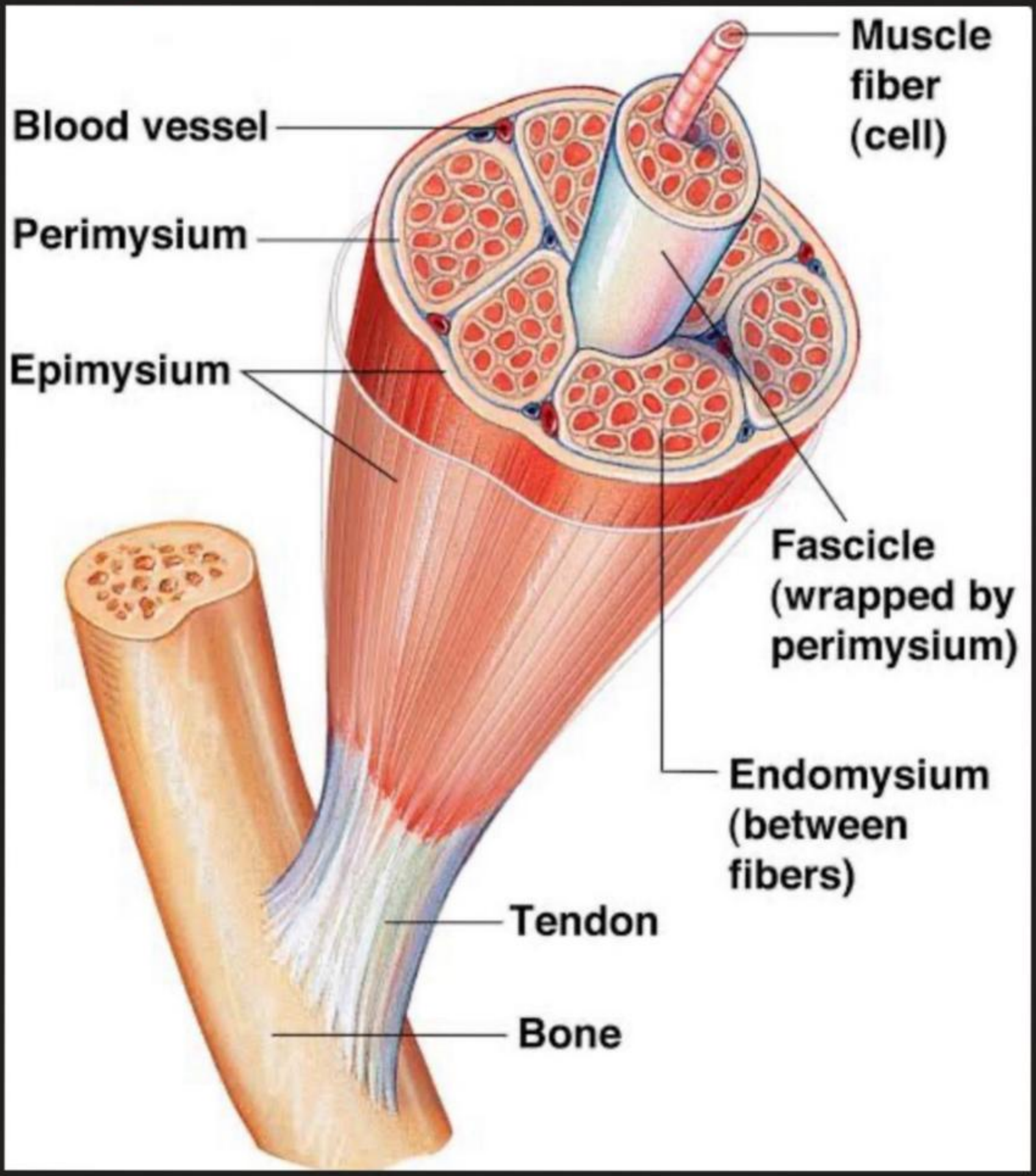
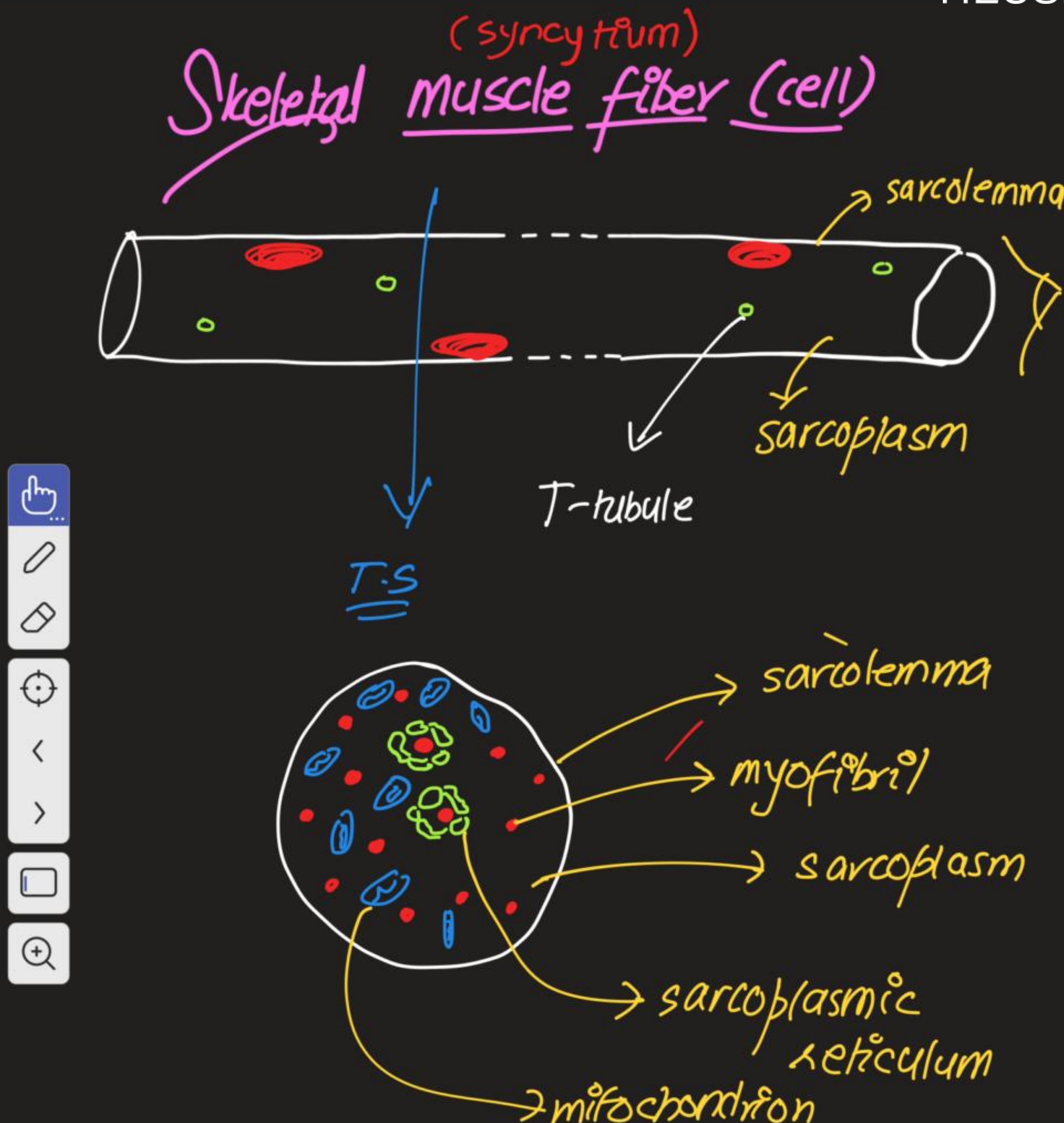
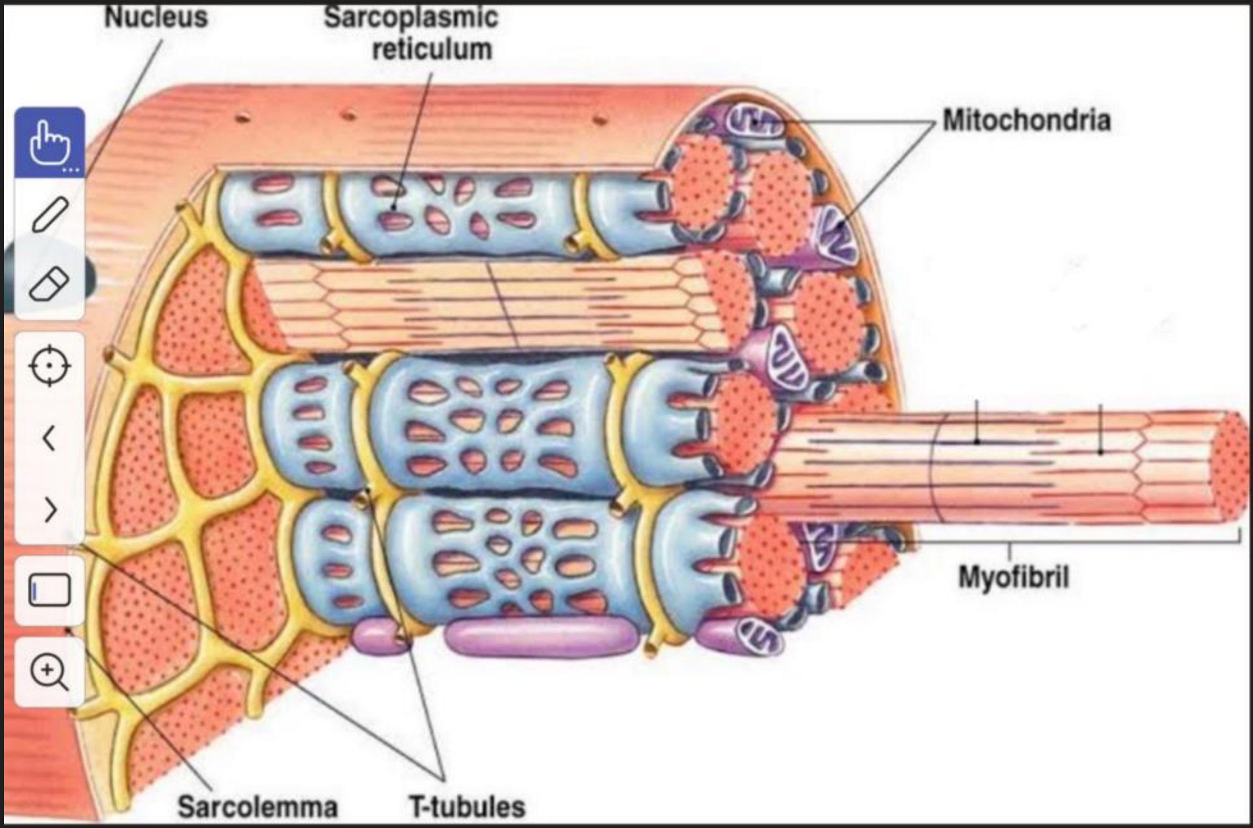
Skeletal muscle fiber (cell)




(syncytium)
Skeletal muscle fiber (cell)
sarcolemma
sarcoplasm
T-tubule
T.S
sarcolemma
myofibril
sarcoplasm
sarcoplasmic reticulum
mitochondrion


Nucleus
Sarcoplasmic reticulum
Mitochondria
Myofibril
Sarcolemma
T-tubules

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Skeletal Muscle Cell

1. A skeletal muscle cell is also termed as the skeletal muscle fibre.

2. Each skeletal muscle cell is cylindrical in shape and contains multiple nuclei.

3. A skeletal muscle cell is also termed as a syncytium because of it's multinucleic nature.

4. The cell membrane of the skeletal muscle cell is termed as the sarcolemma.

SKELETAL MUSCLE STRUCTURE

① Skeletal muscles are also termed as striated muscles.

② Skeletal muscles are under voluntary control.

③ A transverse section of a skeletal muscle ~~cell~~ shows bundles of muscle cells termed as fascicles.

④ Each fascicle contains numerous skeletal muscle cells.

⑤ Individual skeletal muscle cells are surrounded by a layer of connective

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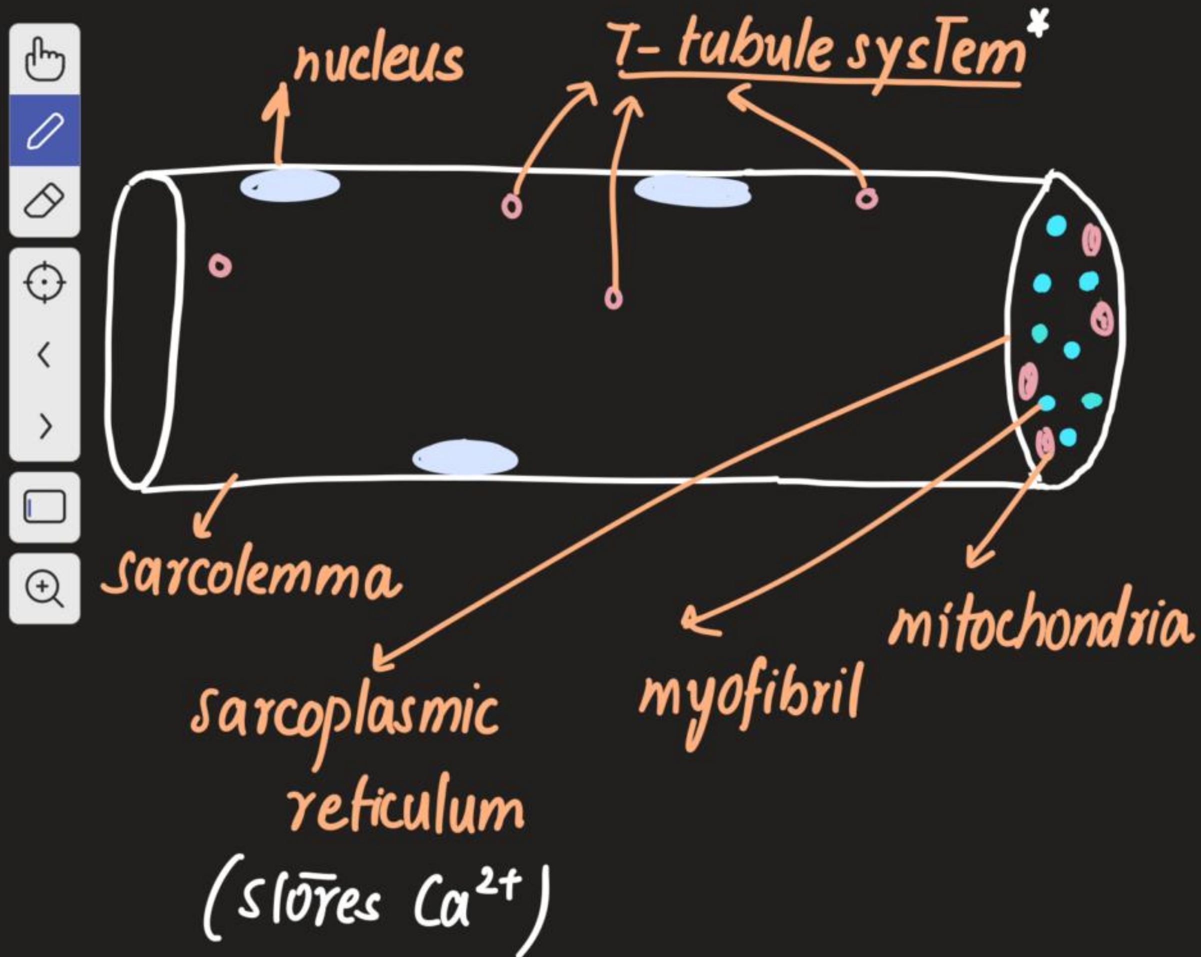
⑤ The cytoplasm of the skeletal muscle cell is termed as sarcoplasm and the endoplasmic reticulum is termed as the sarcoplasmic reticulum. The sarcoplasmic reticulum stores Calcium ions.

⑥ Each skeletal muscle cell contains numerous myofibrils which are made up of myofilaments.

⑦ Numerous mitochondria are present within the sarcoplasm to provide energy in the form of ATP for muscular contraction.

(8) The surface of a skeletal muscle cell shows a striated (striated) appearance.

Skeletal Muscle Cell → Surface View



* T-tubule system are the invaginations of the sarcolemma which run transversely through the cross-section of a muscle cell.

* T-tubule system lies adjacent and close to the sarcoplasmic reticulum.

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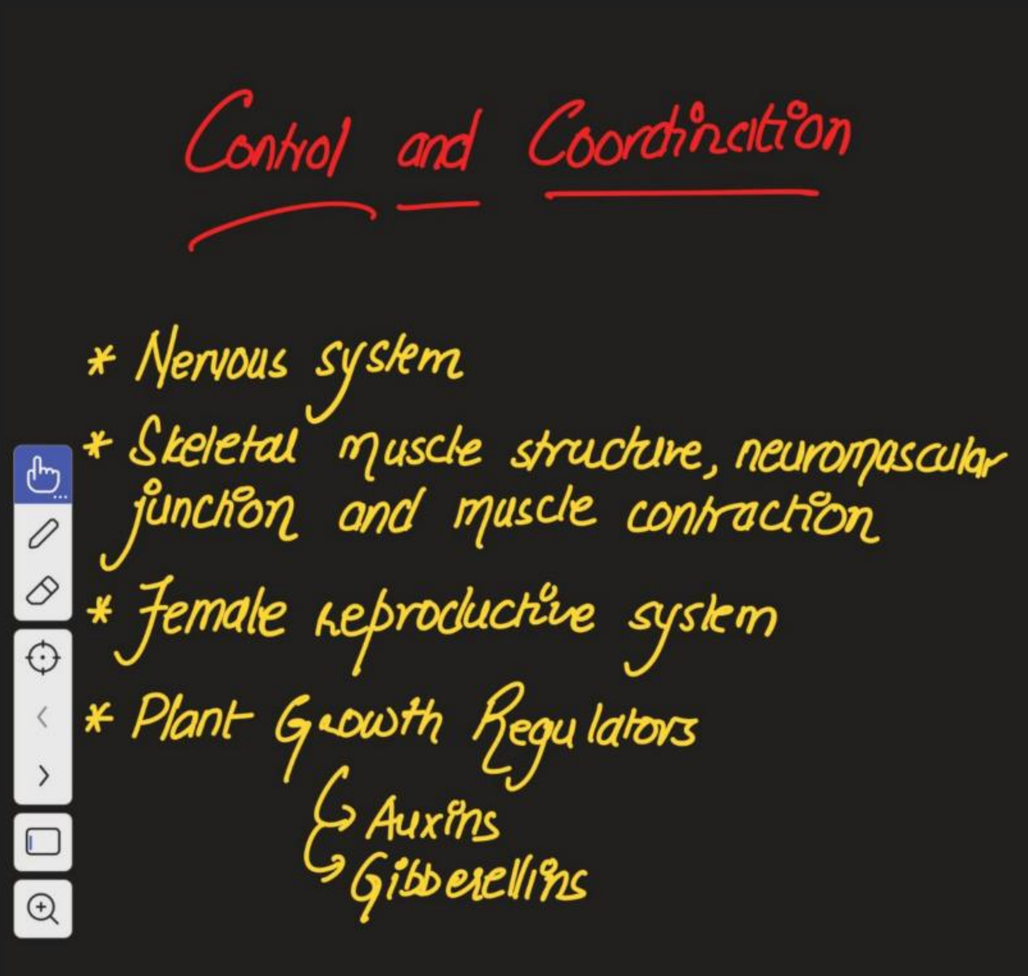
Control & Coordination



With
Mohammad Hussham Arshad, MD

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ADVANCED LEVEL BIOLOGY 9700
UNIT 15: Control & Coordination

Learning Objectives:

- Skeletal Muscle Structure 2
- (Myofibrils, myofilaments & sarcomeres)

Video Lecture Slides

Mohammad Hussham Arshad, MD
Biology Department

Control and Coordination

* Nervous system
* Skeletal muscle structure, neuromascular junction and muscle contraction
* Female reproductive system
* Plant Growth Regulators
  - Auxins
  - Gibberellins

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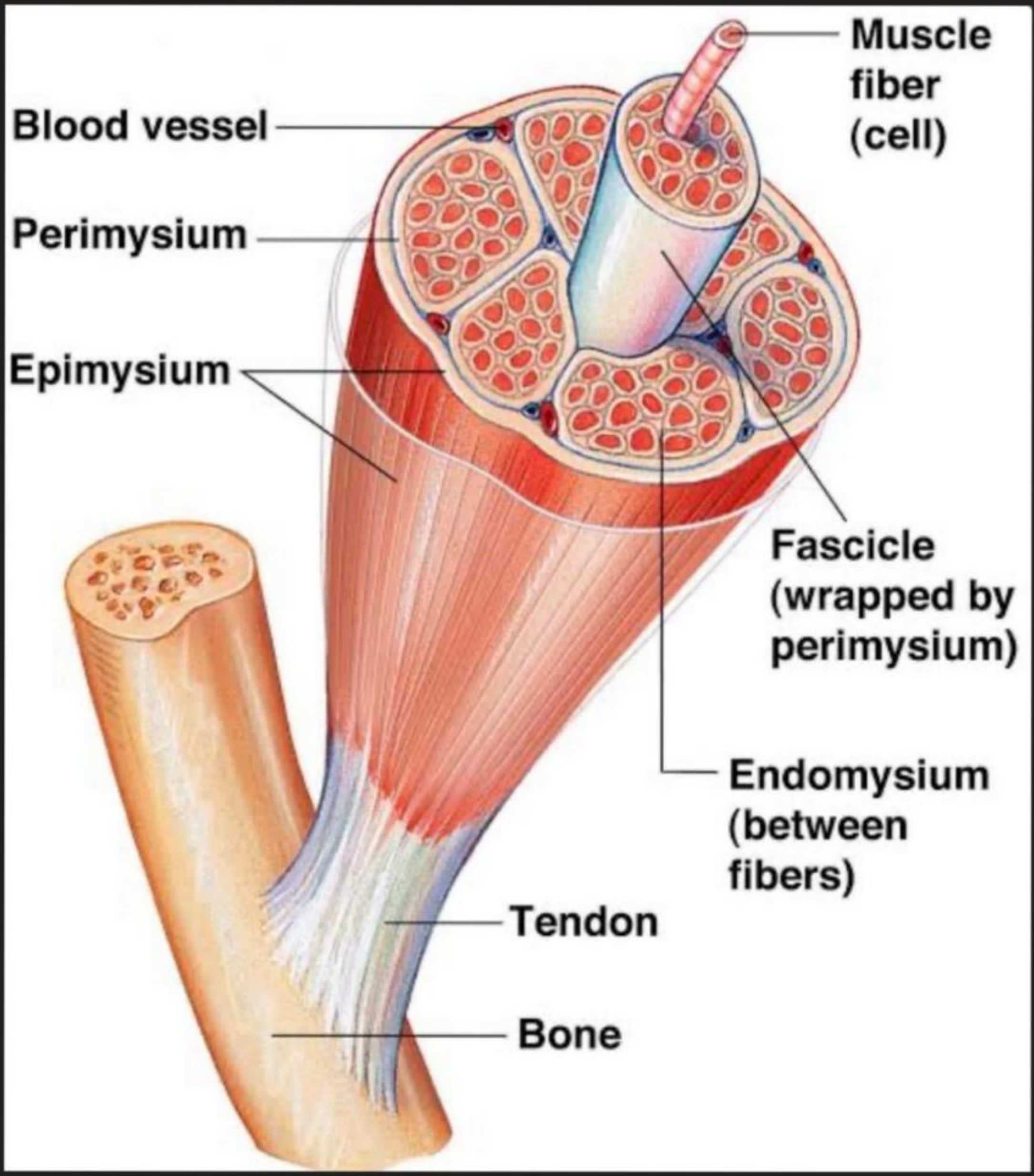
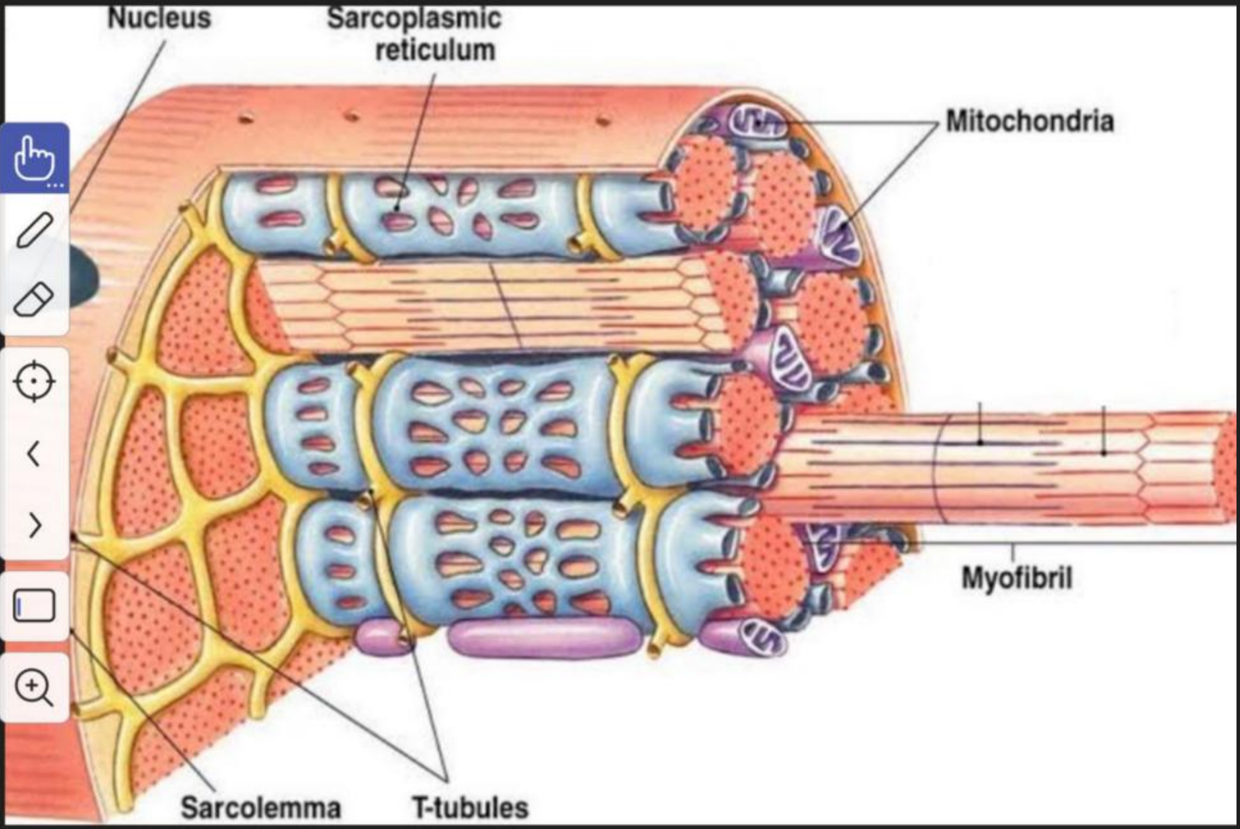
Skeletal Muscle Structure, Neuromuscular function and muscular contraction

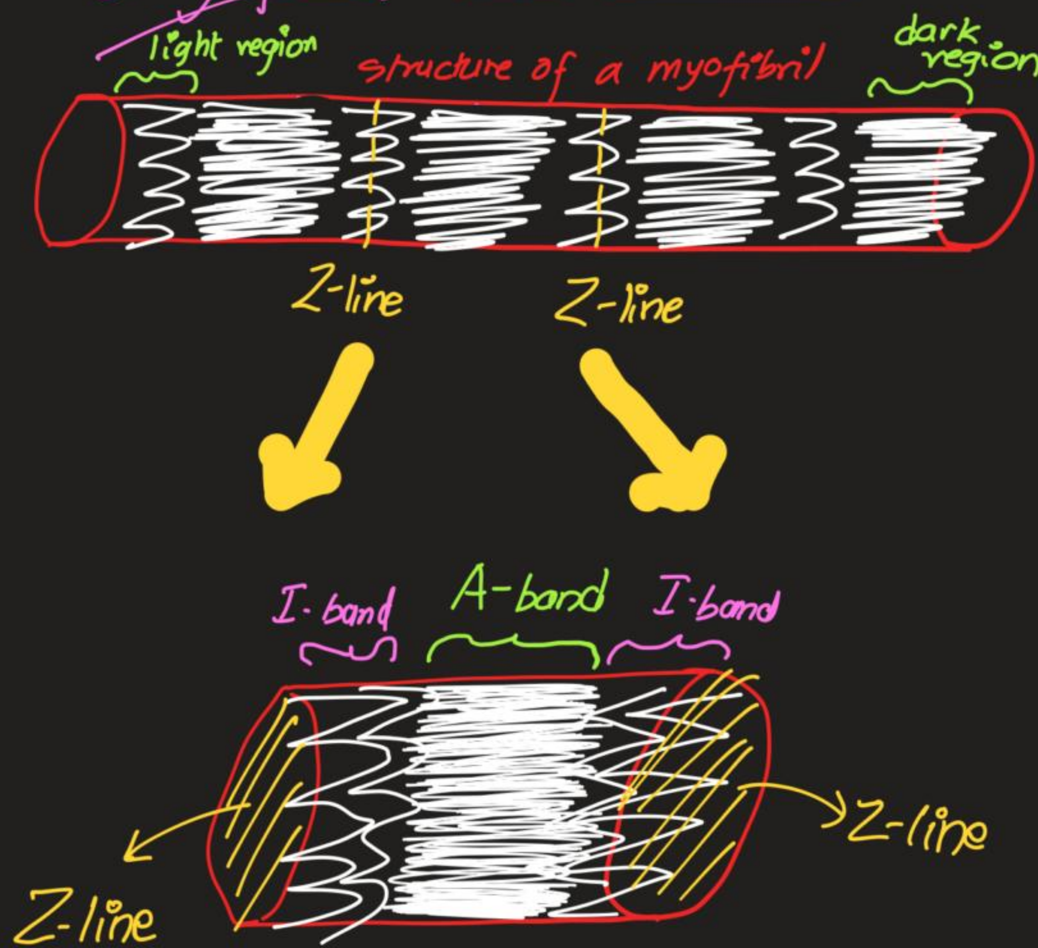
Skeletal muscle structure



Muscle fiber and myofibrils



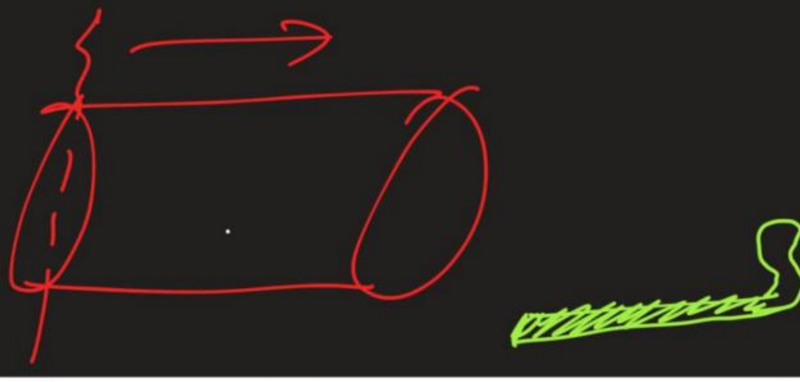
Myofibril and sarcomeres

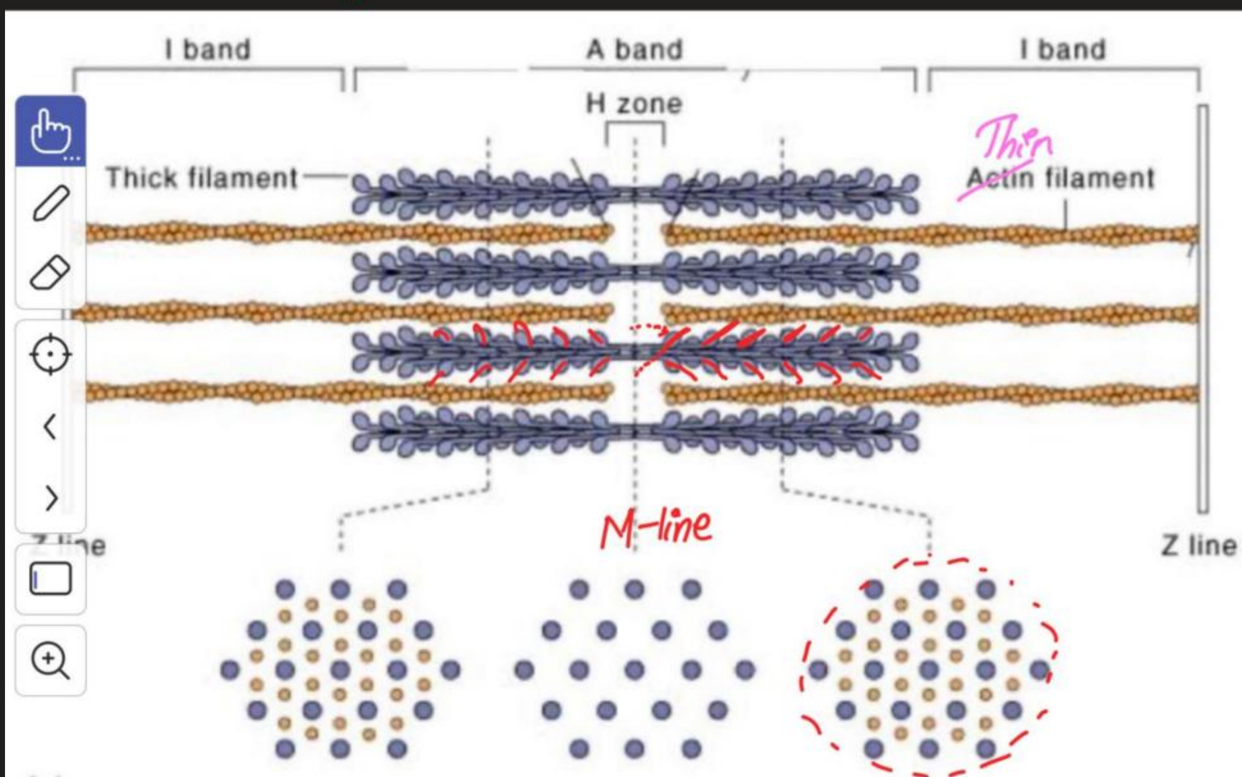


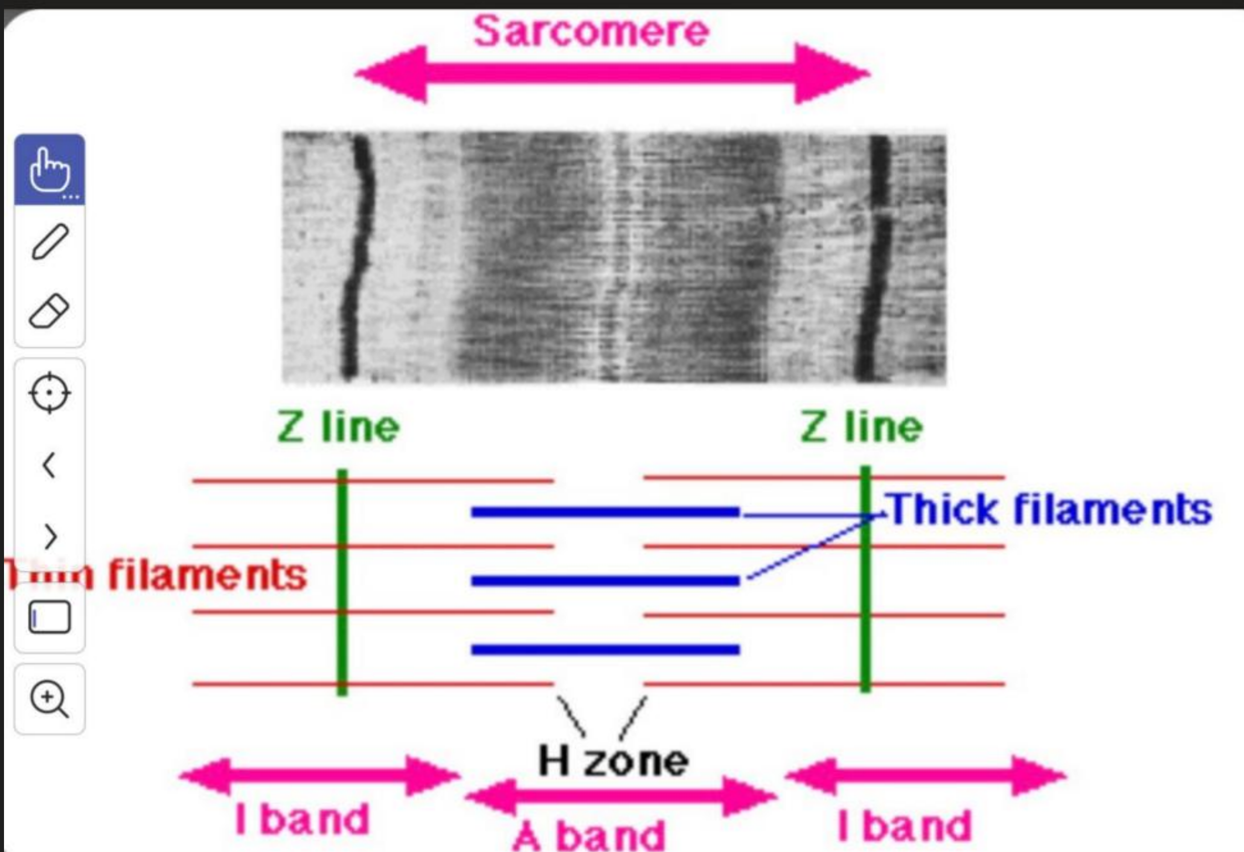
myofilaments

Thick fil.
- myosin

Thin fil.
- actin
- tropomyosin
- troponin

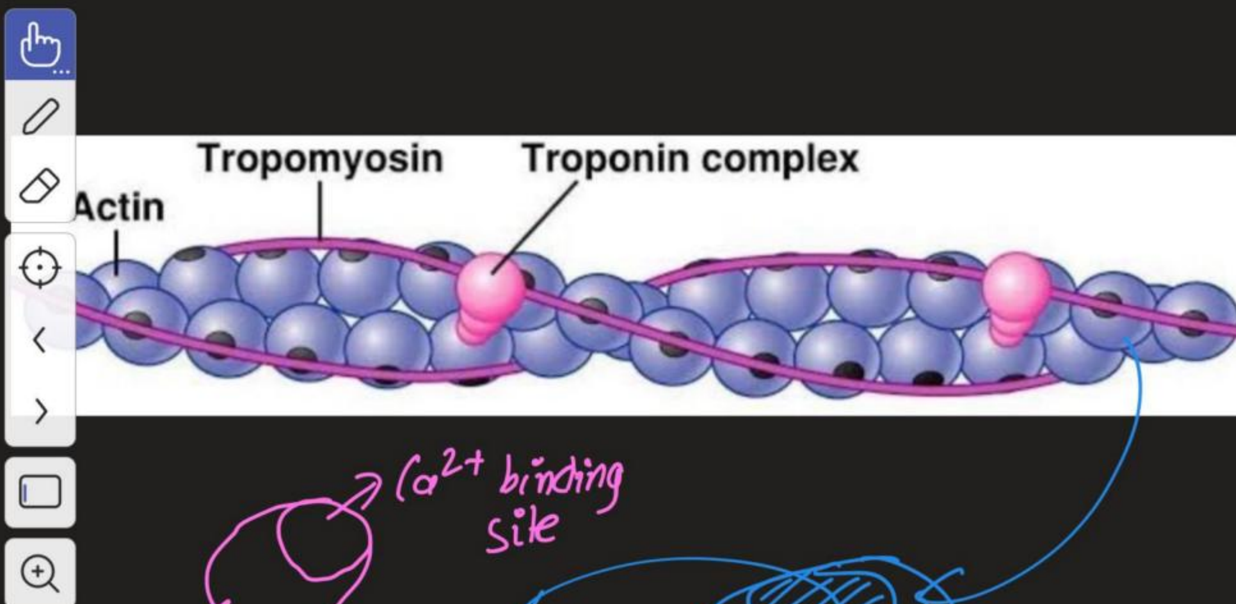


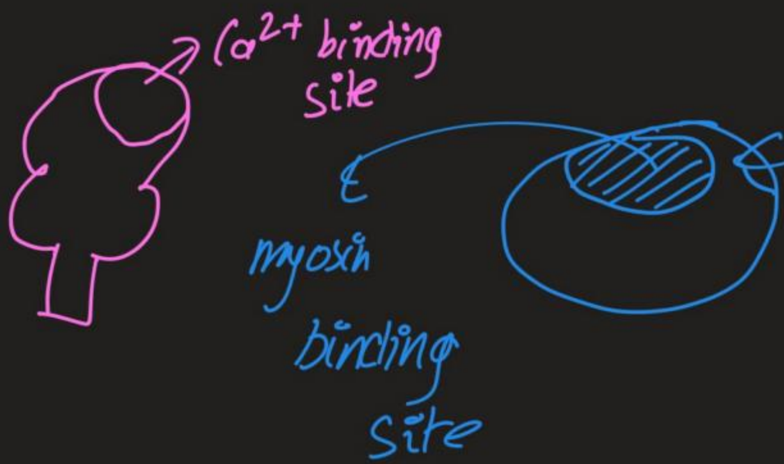

I band
A band
I band
H zone
Thick filament
Thin
Actin filament
M-line
Z line


Sarcomere
Z line
Z line
Thick filaments
filaments
H zone
I band
A band
I band

Thin filament

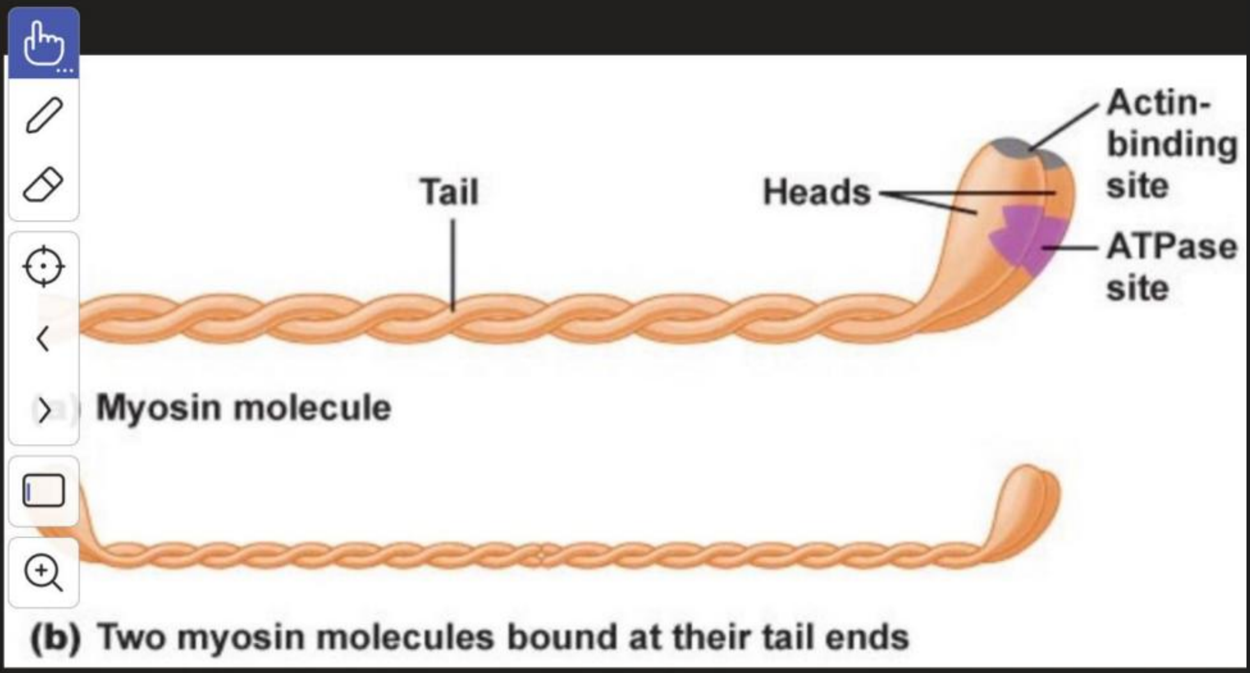
- Troponin
- Tropomyosin
- Actin

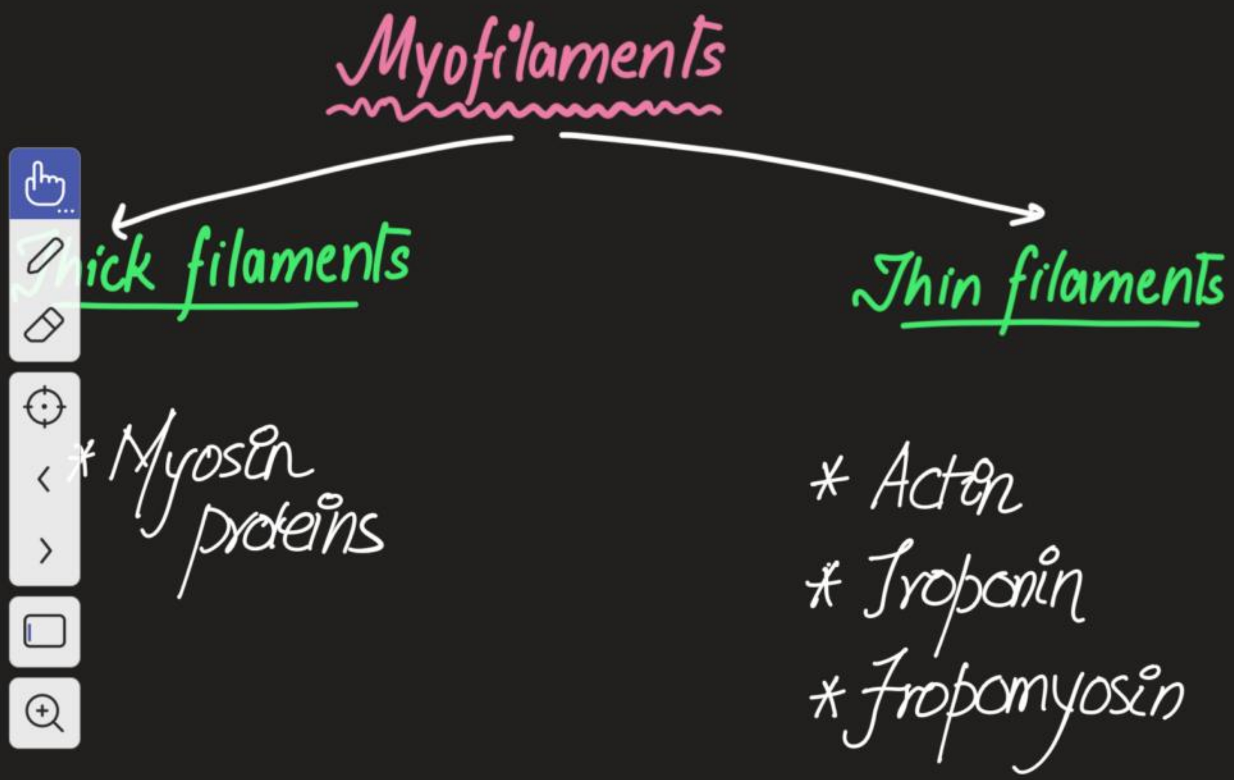




Thick filament

→ Myosin




Myofilaments
Thick filaments
Thin filaments
* Myosin proteins
* Actin
* Troponin
* Tropomyosin

1. numerous myofilaments make up a myofibril.
2. myofilaments are of two types:
   - (A) Thick filaments
   - (B) Thin filaments

A) Thick filaments

→ Thick filaments are composed of the protein myosin.

→ Each myosin protein has a globular head and fibrous tail.

→ The globular head is the enzyme

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ATPase which hydrolyses ATP to release energy.

→ Numerous myosin proteins lay parallel to each other to form the thick filament.

→ The globular head of the myosin protein are flexible in nature and point away from the M-line when the muscle is in its relaxed state.

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B) Thin filaments

→ Thin filaments are made up of the following three proteins:

a) actin b) troponin c) tropomyosin

• Numerous actin proteins associate with each other to form a chain like structure. Each actin protein has a myosin binding site to which the head of the myosin protein binds.

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- Tropomyosin is a fibrous spiral protein which runs along the thin filament covering the myosin binding sites on the actin proteins.

- Troponins are bound to tropomyosin proteins. Each troponin protein has a binding site for Ca^{2+} ions.

SARCOMERE

* Functional unit of a muscle cell characterised by the distance between two consecutive Z-lines.

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Structure of a sarcomere

* Sarcomere is a functional unit of a muscle cell.

* A myofibril contains numerous sarcomeres arranged end-to-end.

* A sarcomere contains the following regions:

A) A-band B) The H-zone C) I-band

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* A-band consists of both thick and thin filaments.
* The H-zone is at the centre of the A-band and contains thick filaments only.
* The I-band contains thin filaments only.
* Muscle striation are due to an alternating arrangement of A-bands (dark regions) and I-bands (light regions)

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* When muscle contraction occurs, the sarcomere shortens.

* The following changes occur within a sarcomere during muscular contraction:
  - → The overall sarcomere reduces in length
  - → The I-band shortens.
  - → The H-zone shortens
  - → The A-band stays the same.

* The adjacent sarcomeres are separated by Z-lines.

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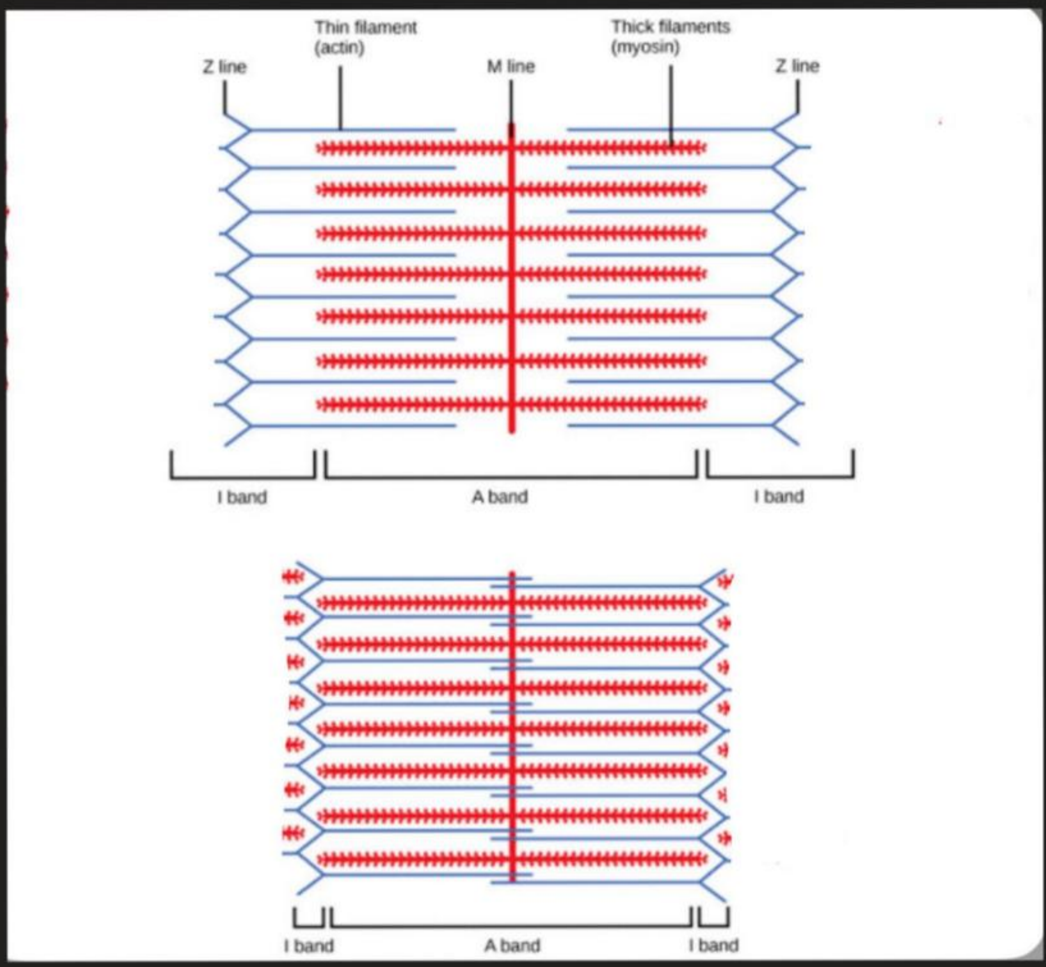
Thin filament (actin)
Thick filaments (myosin)
Z line
M line
Z line
I band
A band
I band
I band
A band
I band

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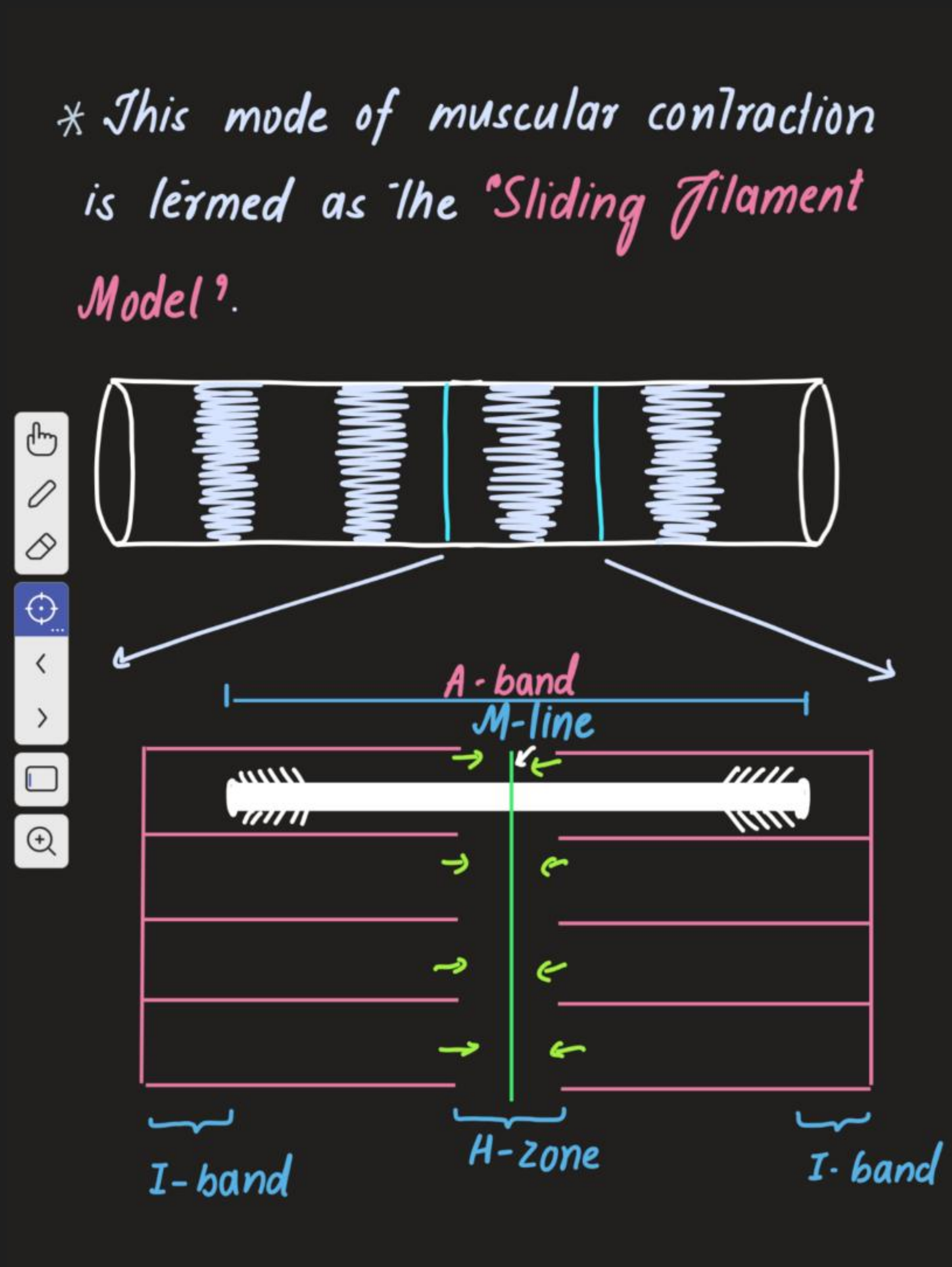
Control & Coordination



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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

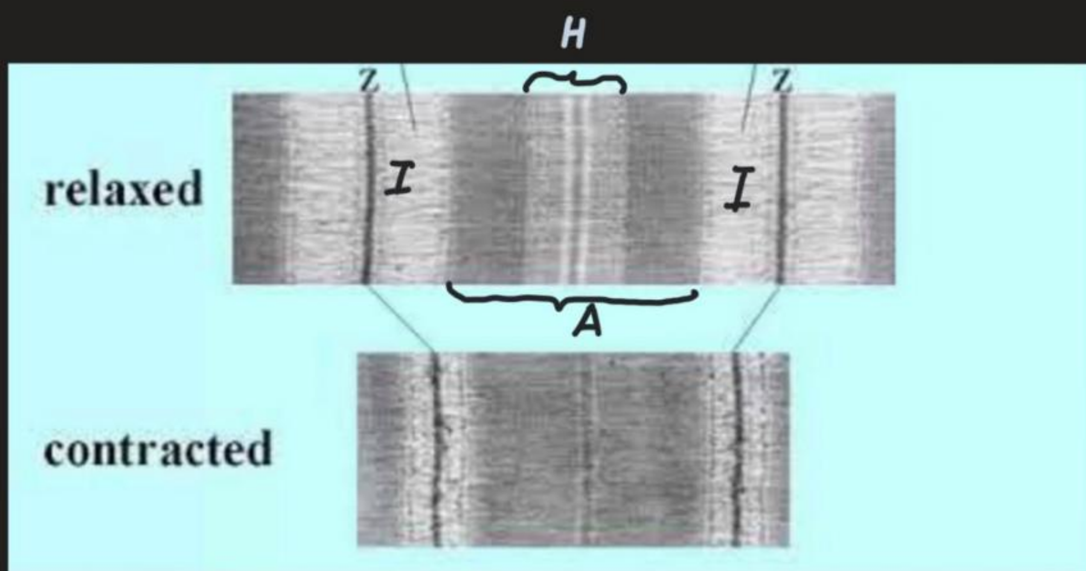
- Neuromuscular junction & muscular contraction
- Sarcomere shortening: sliding filament model

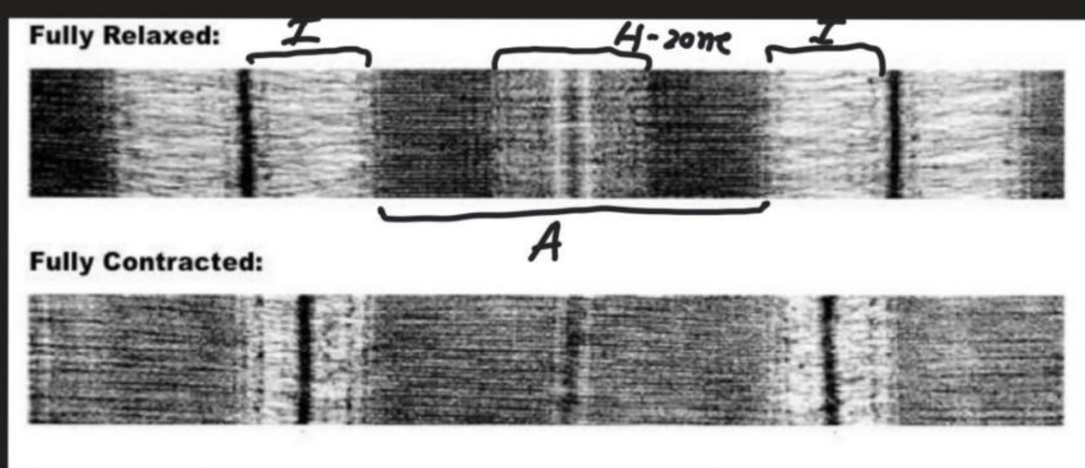
Video Lecture 10 Slides

Mohammad Hussham Arshad, MD
Biology Department

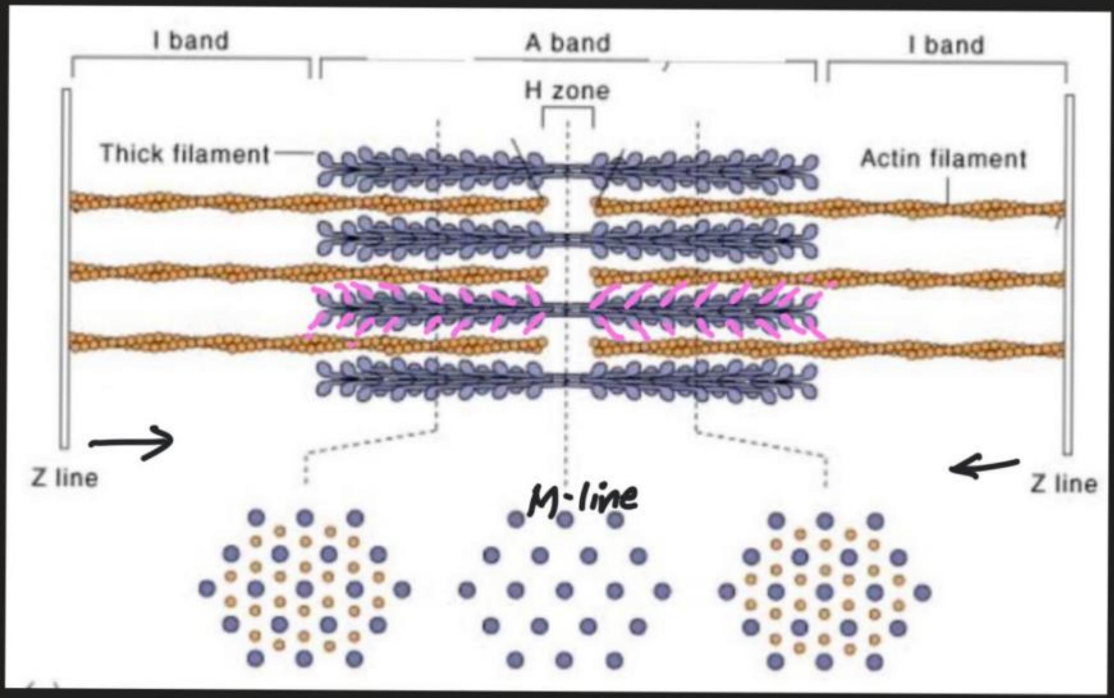
Skeletal Muscle Structure, Neuromuscular function and muscular contraction

Sarcomere shortening



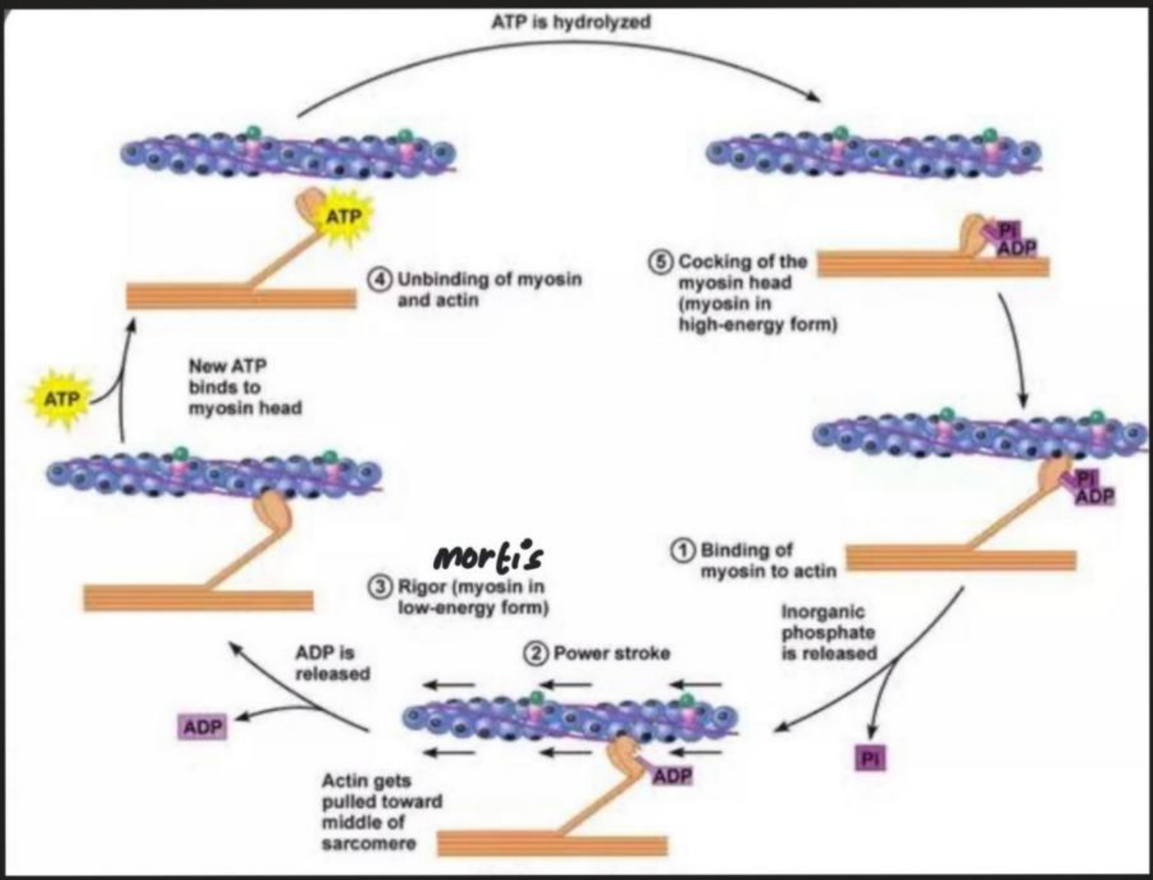


SARCOMERE


I band
A band
I band
H zone
Thick filament
Actin filament
Z line
M-line
Z line

Sarcomere shortening —
sliding filament model

Sarcomere shortening – sliding filament model



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Sarcomere shortening

=> Sarcomere shortening occurs in the following sequence:

* The myosin head hydrolyses ATP to release energy which activates the myosin head.
* Ca^{2+} ions within the sarcoplasm bind to troponin molecules causing them to change their shape which displaces the tropomyosin from the myosin

binding sites on the actin proteins.

* The activated myosin head thereafter attaches to the myosin binding site to form a cross-bridge.

* The myosin head bends towards the M-line causing the sarcomere to shorten. This is known as the power stroke.

* An ATP molecule binds to the myosin head causing it to detach from the actin protein.

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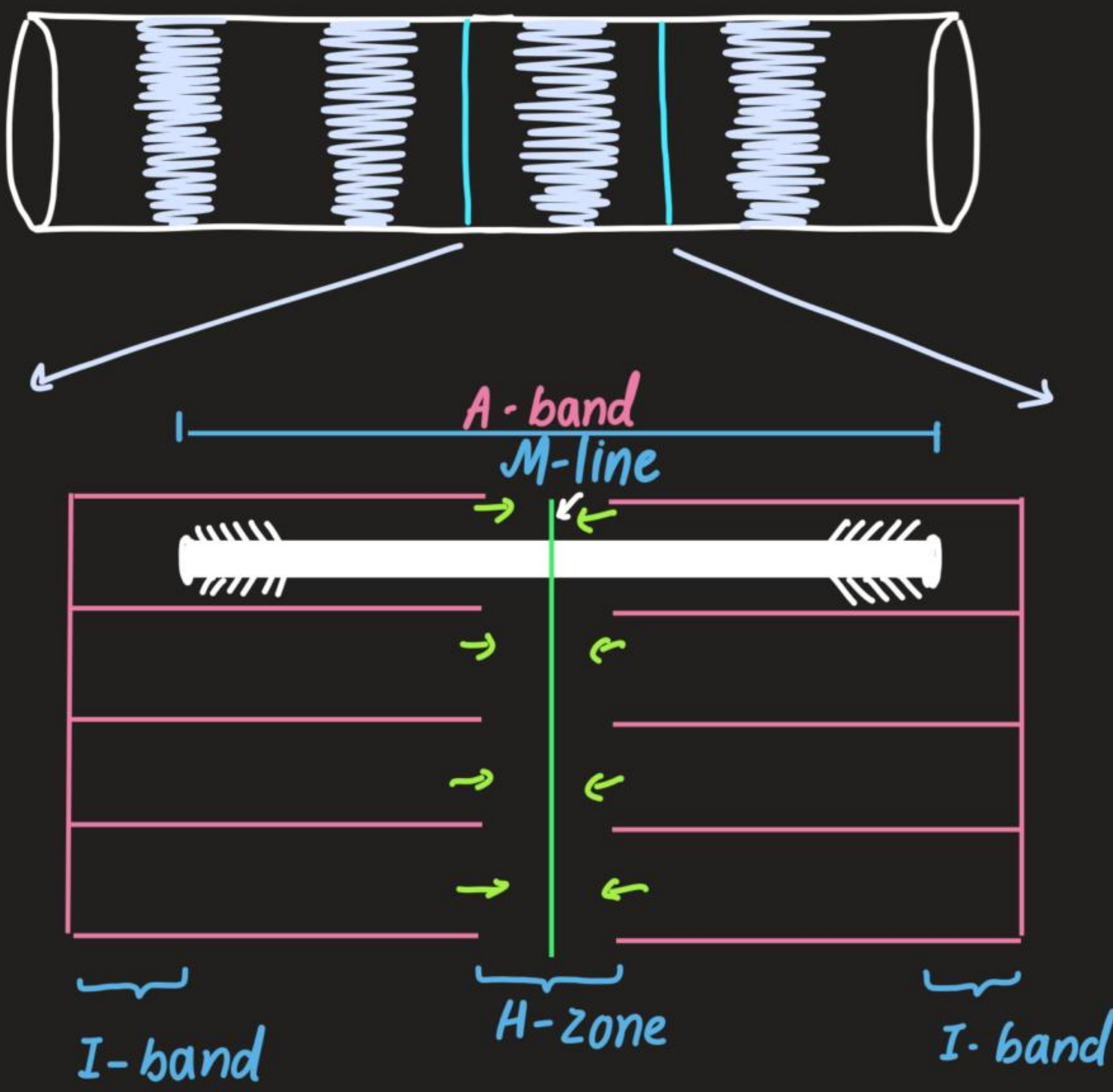
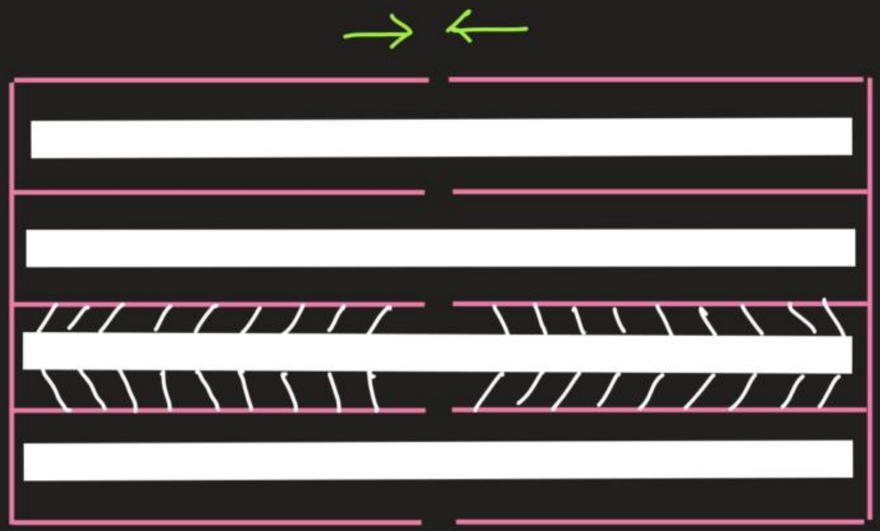
* This mode of muscular contraction is termed as the 'Sliding Filament Model'.



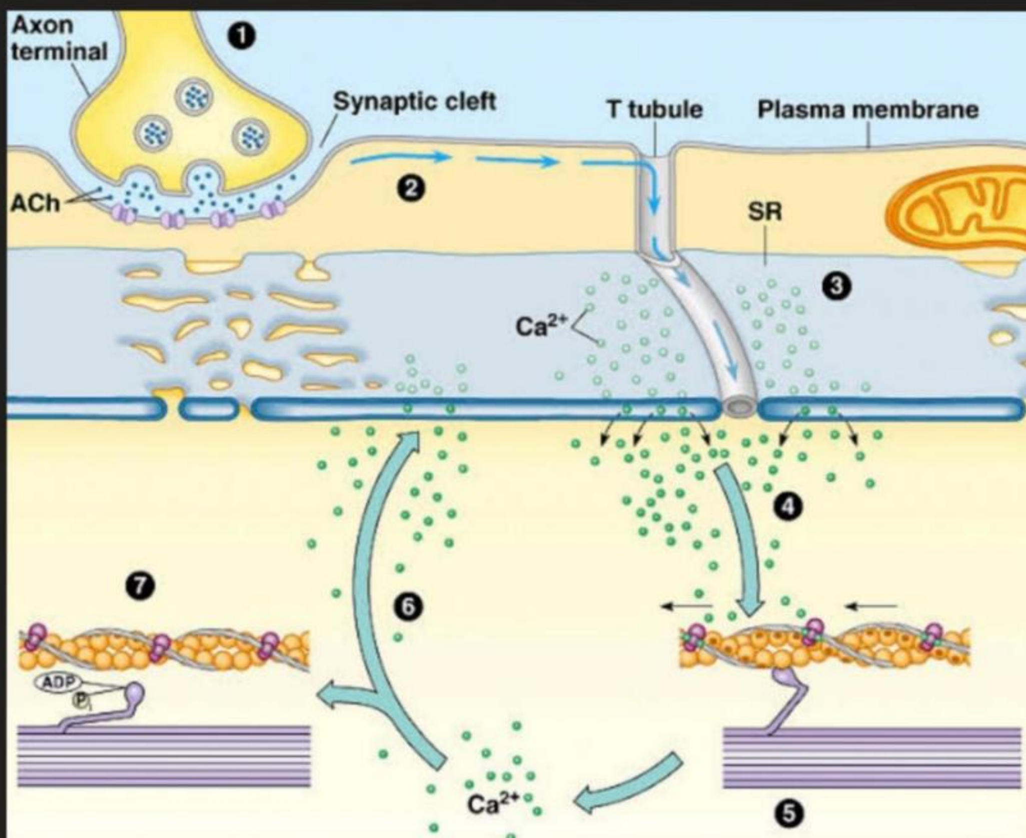


When muscle contracts :

* sarcomere → shortens
* A- band → same width
* I- band → shortens
* H- zone → shortens

Neuromuscular junction and muscle contraction

Sequence of events



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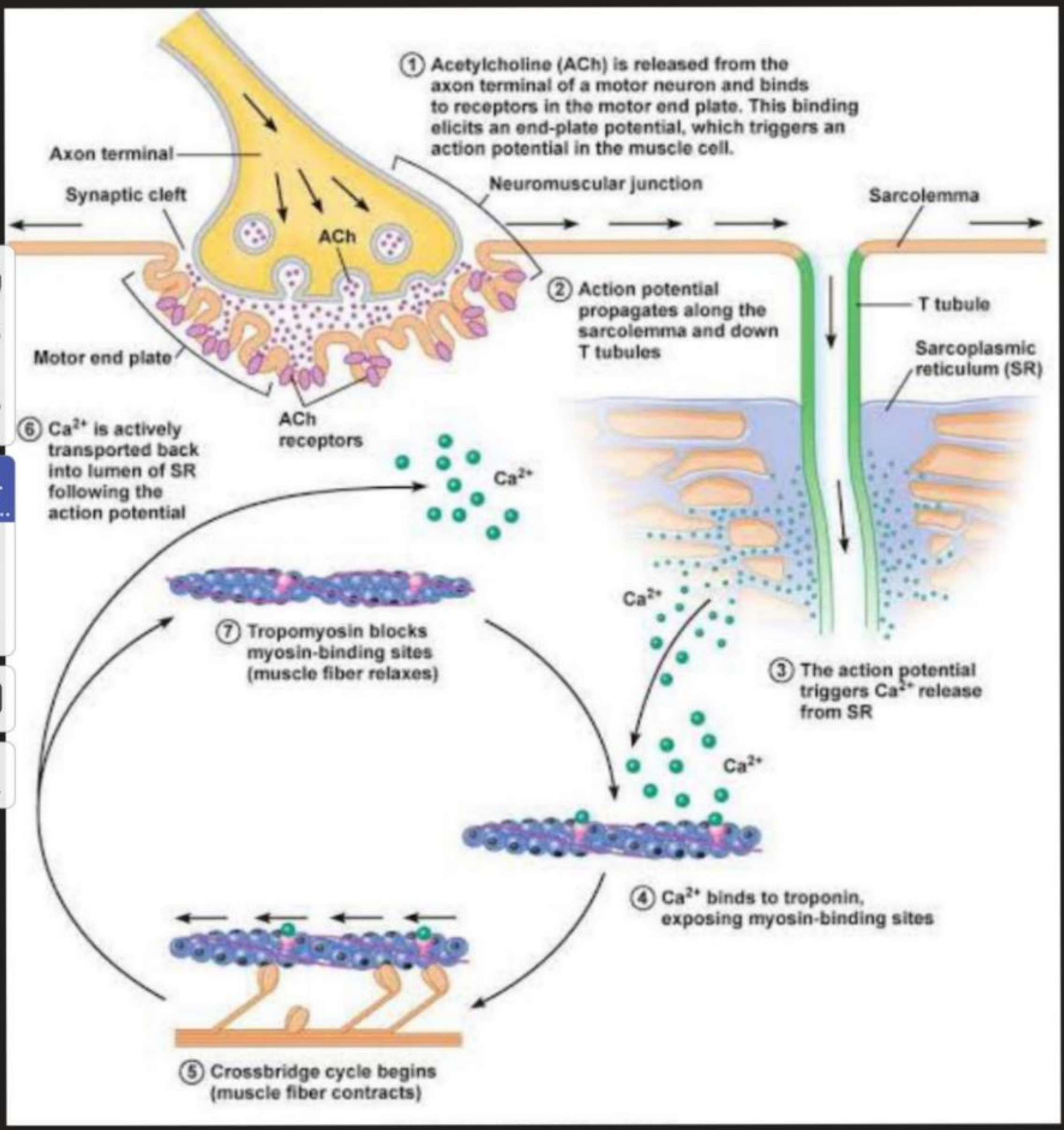
① Acetylcholine (ACh) is released from the axon terminal of a motor neuron and binds to receptors in the motor end plate. This binding elicits an end-plate potential, which triggers an action potential in the muscle cell.
Axon terminal
Synaptic cleft
Neuromuscular junction
Sarcolemma
ACh
Motor end plate
ACh receptors
② Action potential propagates along the sarcolemma and down T tubules
T tubule
Sarcoplasmic reticulum (SR)
⑥ Ca^{2+} is actively transported back into lumen of SR following the action potential
Ca^{2+}
⑦ Tropomyosin blocks myosin-binding sites (muscle fiber relaxes)
③ The action potential triggers Ca^{2+} release from SR
④ Ca^{2+} binds to troponin, exposing myosin-binding sites
⑤ Crossbridge cycle begins (muscle fiber contracts)

Essay questions

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Q1: Briefly describe how an electrical impulse in a motor neurone leads to muscular contraction? [10]

Ans: Depolarisation of the motor neurone opens voltage-gated Calcium ion channels leading to calcium ion influx into the motor neurone. This causes vesicles containing acetylcholine to fuse with the presynaptic membranes releasing Ach via exocytosis. Ach diffuses along the synaptic cleft and binds to its receptors

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on the sarcolemma. This depolarises the sarcolemma. The depolarisation travels down the ~~transverse~~ T-tubule system which makes the sarcoplasmic reticulum leaky, opening the VG – Ca^{2+} channels. Ca^{2+} leave the sarcoplasmic reticulum to enter the sarcoplasm where they bind to troponin molecules. This displaces the tropomyosin from the myosin binding sites on the actin protein. The activated myosin head binds to the actin protein to form a cross-bridge. The myosin head thereafter bends towards the M-line causing the muscle to contract. This mode of muscular contraction is termed as the 'sliding filament model'.

HEUSER

Q2: Outline the role of Ca^{2+} ions in muscular contraction? [8]

Ans: An action potential arrives at the motor neurone which opens the VG-Ca^{2+} ion channels enabling Ca^{2+} ion entry into the neurone. These ions stimulate the movement of vesicles containing Ach towards the motor neurone membrane. Vesicles fuse with the membrane releasing Ach into the synaptic cleft via exocytosis. Ach binds to its receptors

HEUSER

depolarising the sarcolemma. The depolarisation travels down the T-tubule system opening VG - Ca^{2+} channels in the sarcoplasmic reticulum. This enables Ca^{2+} ions to travel down the conc. gradient into the sarcoplasm. Ca^{2+} ions bind to troponins promoting sarcomere shortening.

The Ca^{2+} ions are pumped back into the sarcoplasmic reticulum in the absence of depolarisation of the sarcolemma.

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Q3: Outline the role of myosin in the sliding filament model of muscle contraction?

Ans: A myosin molecule contains a globular head and a fibrous tail. This head is an enzyme ATPase which hydrolyses ATP to form ADP and inorganic phosphate. The energy released activates the myosin head. It attaches to the myosin binding site on the actin to form a cross-bridge. ADP and inorganic phosphate detaches from the myosin head. The head bends towards the M-line, shortening the sarcomere. This is the power stroke. A new ATP molecule attaches to the myosin head detaching it from the thin filament. The head restores its original position. This is the recovery stroke.

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Q4: Briefly describe the role of Troponin and Tropomyosin in muscle contraction?

Ans: Troponin is a regulatory protein in the thin filament which binds to Calcium ions. This binding changes the shape of the Troponin molecules which displaces tropomyosin exposing the myosin binding sites on the actin.

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Tropomyosin is a regulatory protein in the thin filaments which covers the myosin binding sites on the actin when the muscle is in a relaxed state. Binding of Ca^{2+} ions to Troponin displaces the Tropomyosin, exposing the myosin binding sites to which the myosin heads bind to cause muscle contraction.

Q5: Briefly describe how a sarcomere lengthens (relaxes) after shortening (contraction)?

Ans: Contraction of the antagonistic muscle relaxes (lengthens) the sarcomere. Sarcomere lengthening also occurs due to active pumping of Ca^{2+} ions back into sarcoplasmic reticulum.

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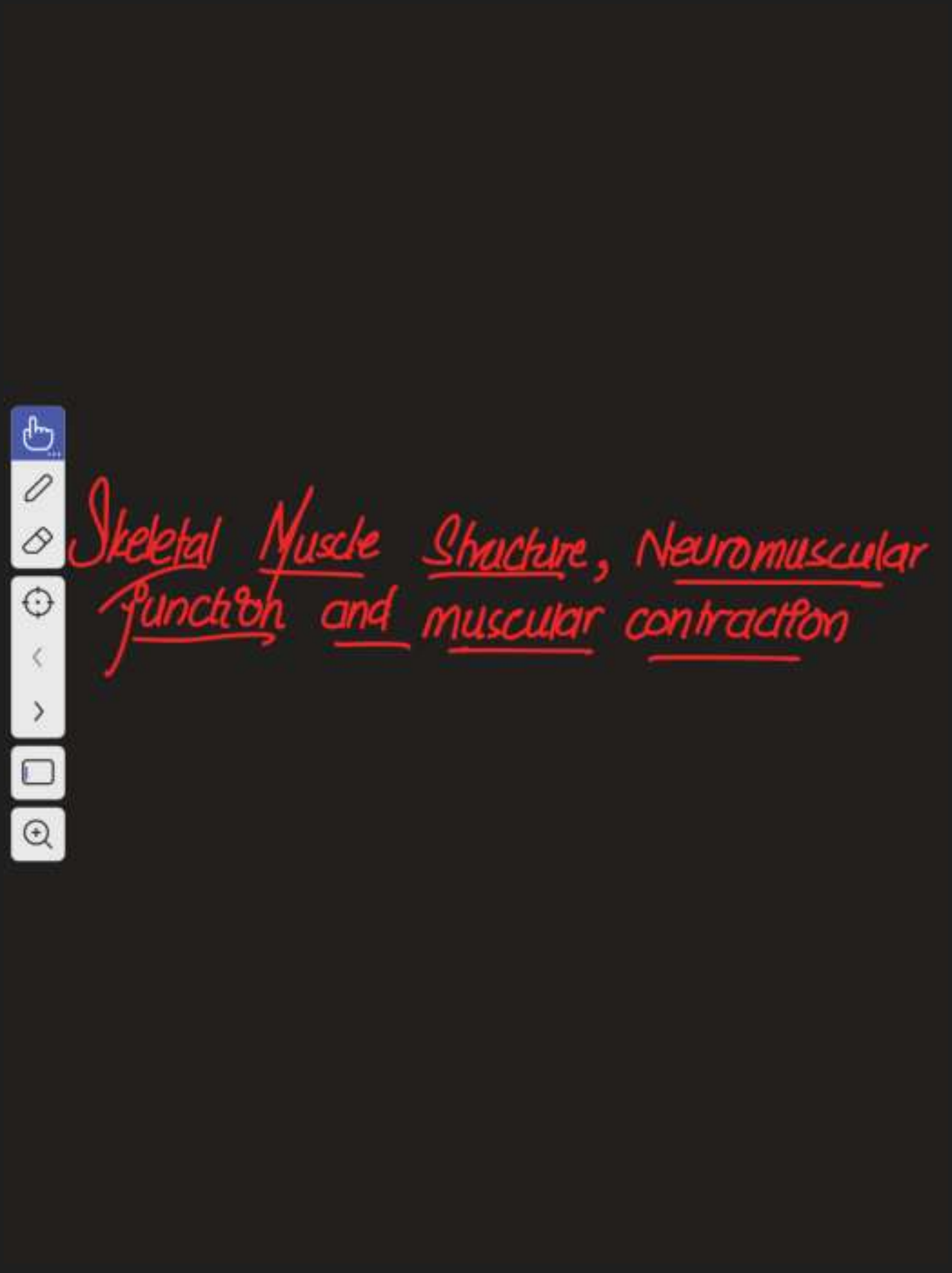
Q6: Briefly describe the role of T-Tubule system?

Ans: T- system of tubules is formed by the invaginations of the sarcolemma. Presence of these tubules enable the skeletal muscle to contract forcefully by synchronising the release of Ca^{2+} ions from the sarcoplasmic reticulum throughout the muscle cells once the sarcolemma depolarises.

Control & Coordination



With

Mohammad Hussham Arshad, MD

ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Skeletal, cardiac & smooth muscles
- Practice questions

Video Lecture 11 Slides

Mohammad Hussham Arshad, MD
Biology Department

Skeletal Muscle Structure, Neuromuscular function and muscular contraction

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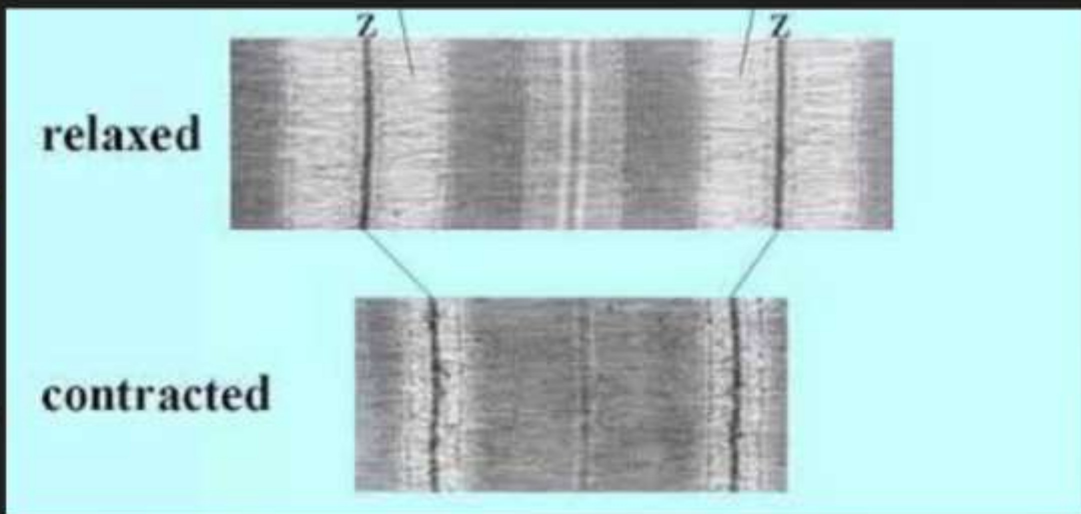
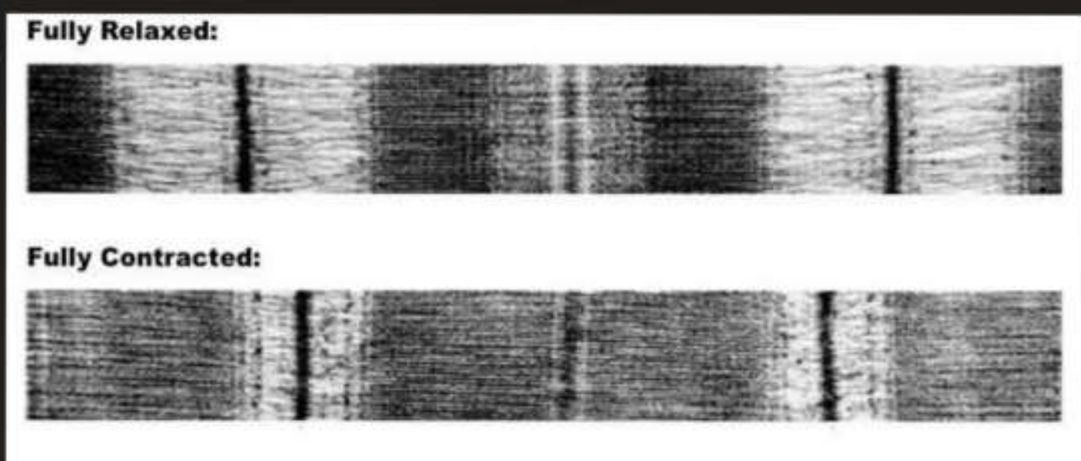
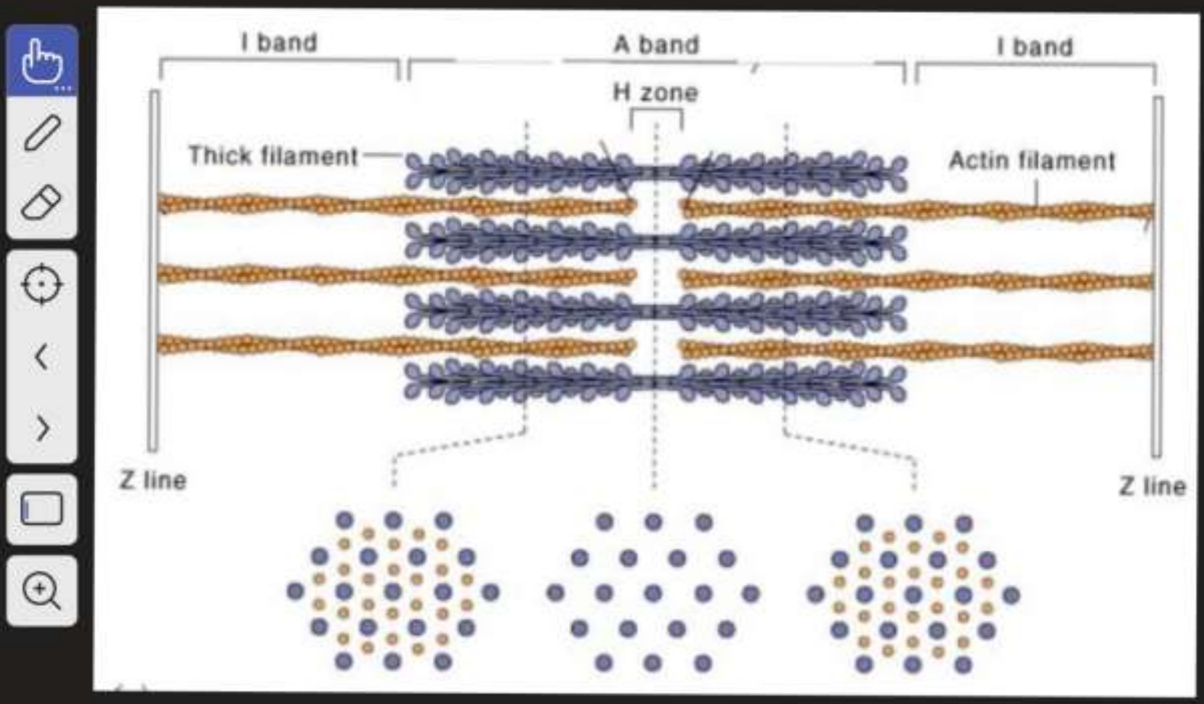
Sarcomere shortening

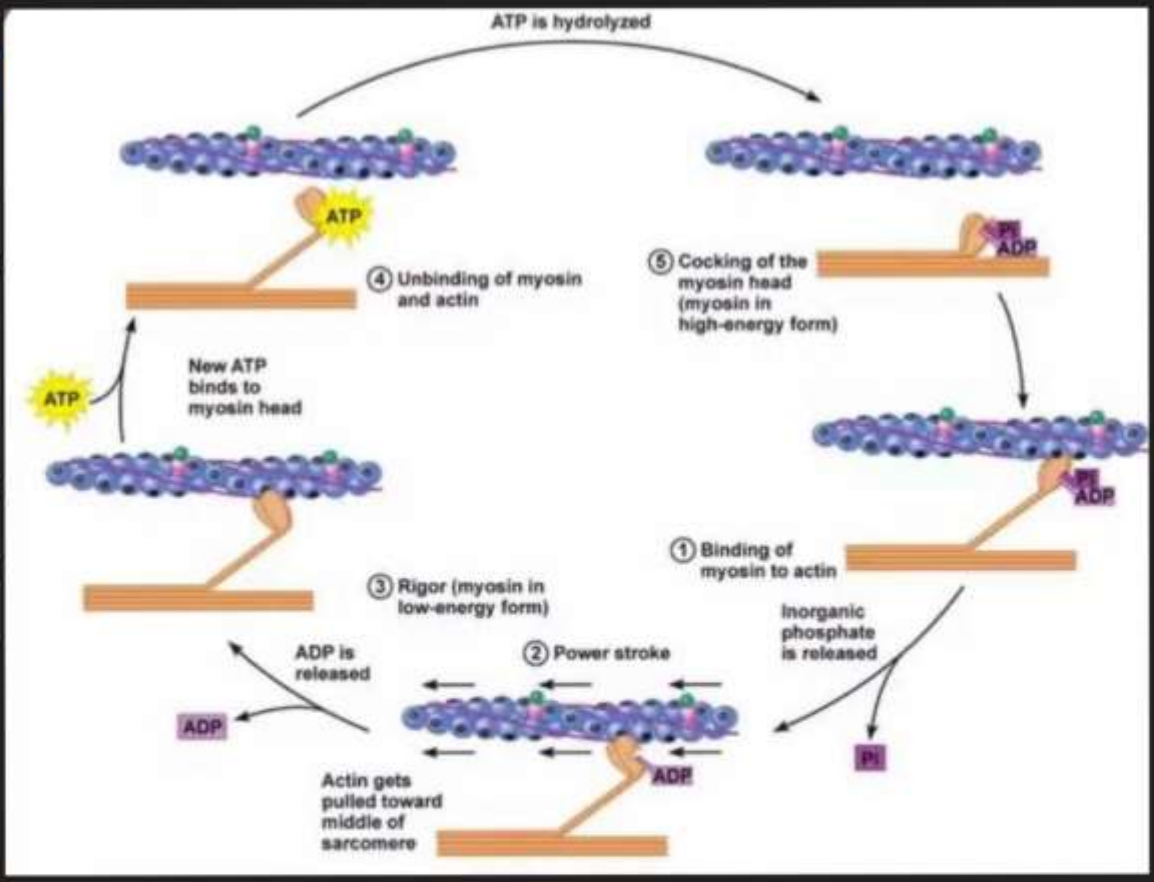




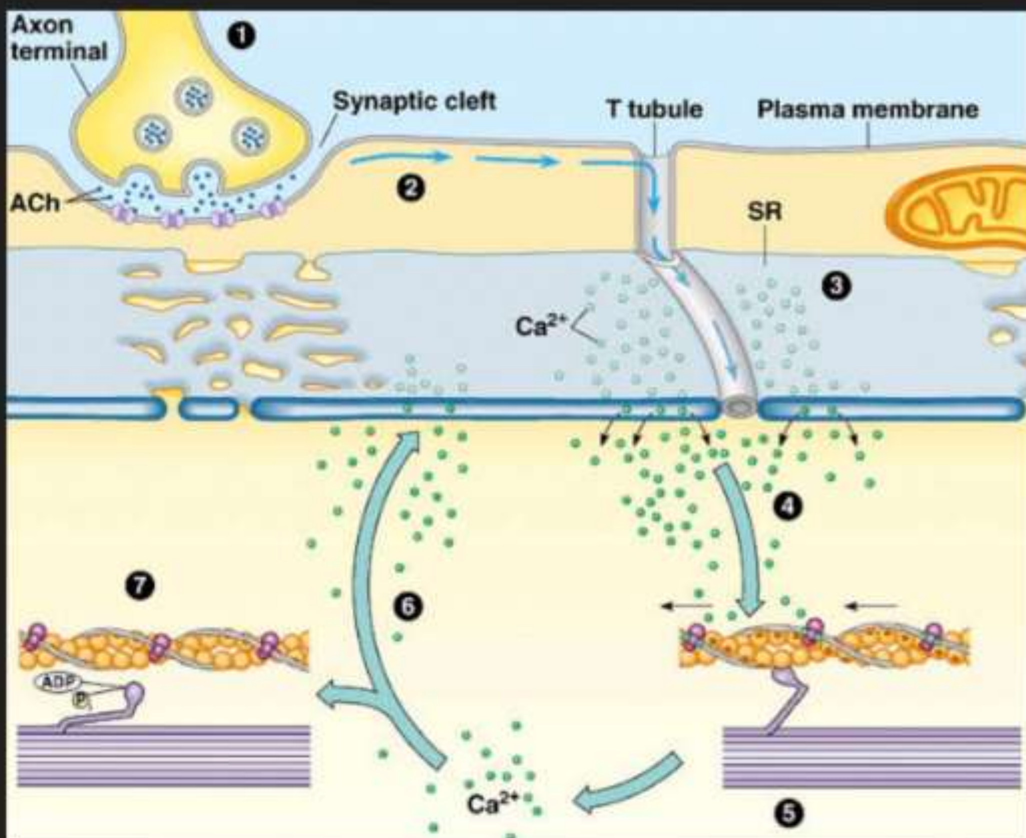
Sarcomere → structure



Sarcomere shortening – sliding filament model



Sequence of events



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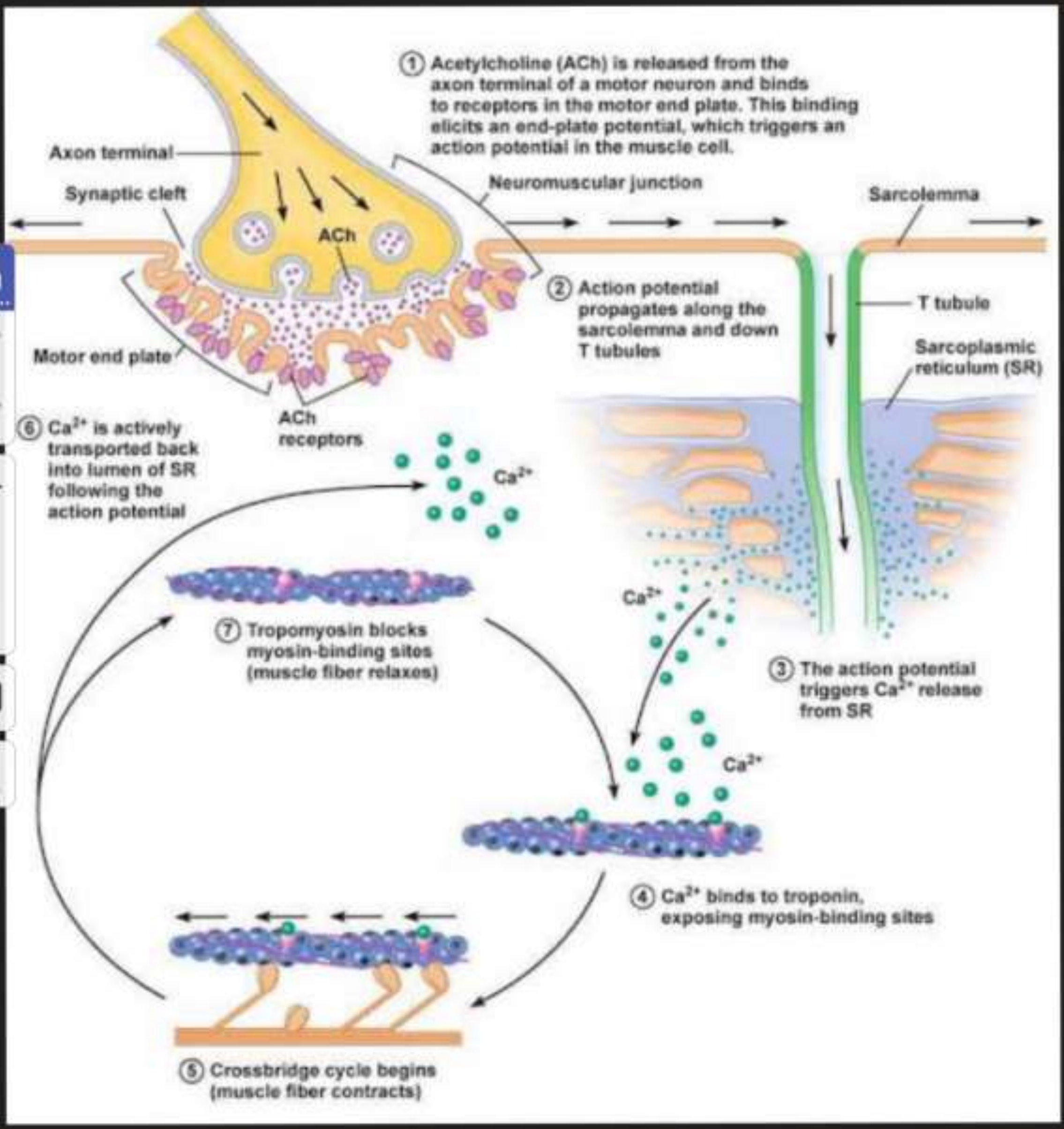
① Acetylcholine (ACh) is released from the axon terminal of a motor neuron and binds to receptors in the motor end plate. This binding elicits an end-plate potential, which triggers an action potential in the muscle cell.
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Synaptic cleft
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Neuromuscular junction
Sarcolemma
Motor end plate
ACh receptors
② Action potential propagates along the sarcolemma and down T tubules
T tubule
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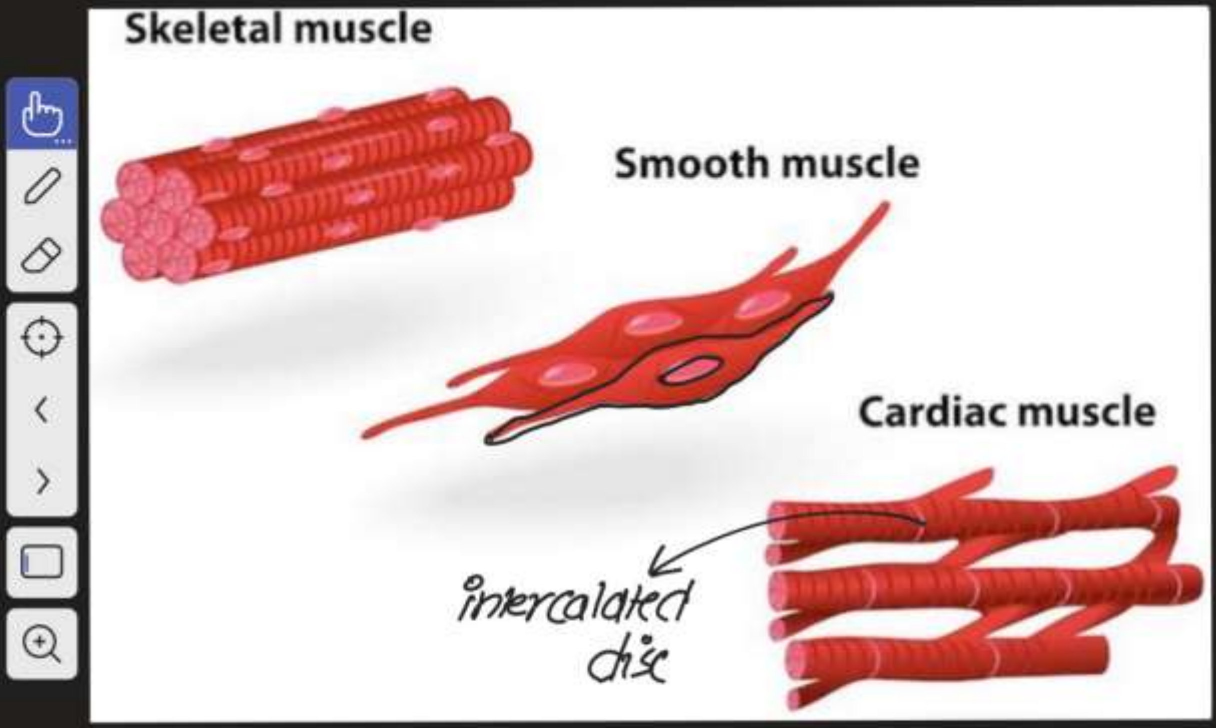
⑥ Ca2+ is actively transported back into lumen of SR following the action potential
Ca2+
⑦ Tropomyosin blocks myosin-binding sites (muscle fiber relaxes)
③ The action potential triggers Ca2+ release from SR
④ Ca2+ binds to troponin, exposing myosin-binding sites
⑤ Crossbridge cycle begins (muscle fiber contracts)

Skeletal, Cardiac and smooth muscles


Skeletal muscle
Smooth muscle
Cardiac muscle
intercalated
disc

Q7: Differentiate between skeletal muscle, cardiac muscles and smooth muscles.

Skeletal	Cardiac	Smooth
① Under voluntary control	involuntary	involuntary
② neurogenic (they need a nerve impulse)	myogenic	neurogenic
③ Cells are long, cylindrical and multi-nucleated.	cylindrical and multi-nucleated	spindle shaped with tapered ends.

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(4) Cells are unbranched	Cells are branched with intercalated disc separating adjacent muscle cells.	Cells are unbranched
(5) Muscles are attached to bones	Cells make up the cardiac tissue	Smooth muscles are present within blood vessels, alimentary canal & ureter.


Questions

7 Fig. 7.1 shows a mammalian neuromuscular junction.

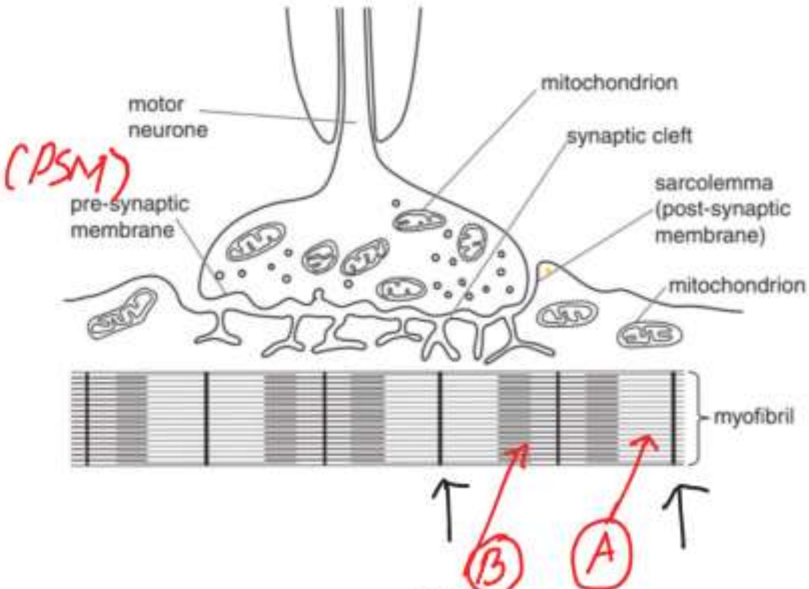

Fig. 7.1

(a) (i) On Fig. 7.1, use label lines and letters to label each of the following parts:

A – a region containing only actin
B – a region containing both actin and myosin. [2]

(ii) Outline how an action potential arriving at this neuromuscular junction can result in depolarisation of the sarcolemma.

* the action potential depolarises the PSM
* which opens voltage gated Ca^{2+} channels
* Ca^{2+} influx into the presynaptic knob
* which will stimulate the vesicles to fuse with the presynaptic membrane
* releasing ACh via exocytosis
* ACh diffuses across the synaptic cleft
* and binds to its receptors on the sarcolemma
* This will depolarise the sarcolemma.

[4]

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(b) Table 7.1 shows some of the events occurring during muscle contraction.
They are **not** listed in the correct order.

Table 7.1

event	description of event
Q	Ca^{2+} ions diffuse out of sarcoplasmic reticulum
R	myosin heads bind to actin
S	sarcolemma depolarised
T	sarcomere shortens
U	Ca^{2+} ions bind to troponin
V	transverse tubules depolarised
W	binding sites on actin exposed
X	myosin heads tilt /bend/ rotate
Y	tropomyosin moves
Z	troponin changes shape

Complete Table 7.2 to show the **correct** order of the events.
Two of the events have been completed for you.

Table 7.2

correct order	letter of event
1	S
2	V
3	Q
4	U
5	Z
6	Y
7	W
8	R
9	X
10	T

[4]

3 Fig. 3.1 shows a diagram of two sarcomeres of relaxed striated muscle.

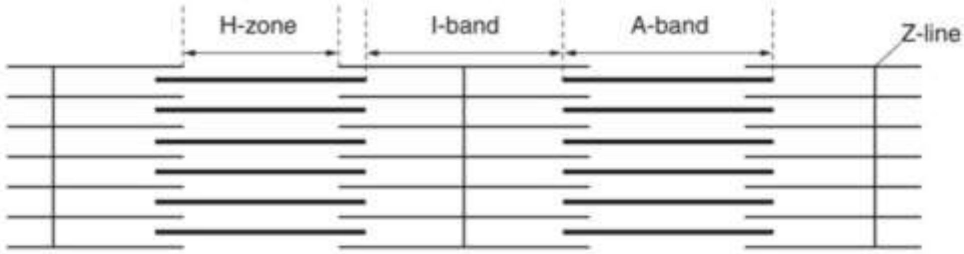

Fig. 3.1

(a) When the striated muscle contracts, state what happens to the length of:

(i) the I-band shortens [1]

(ii) the A-band. same length [1]

(b) Describe how the response of the sarcoplasmic reticulum to the arrival of an action potential leads to the contraction of striated muscle.

* sarcoplasmic reticulum is depolarised
* opens voltage-gated Ca^{2+} channels enabling Ca^{2+} to diffuse into the sarcoplasm
* Ca^{2+} bind to troponins which change their shape
* tropomyosin moves exposing the myosin binding sites on the actin
* this allows the myosin heads to bind to the actin to form cross bridges
* Myosin head bends (powerstroke) to cause muscle contraction. [4]

(c) Glycogen storage disease type V (GSDV) is a metabolic disorder where stored glycogen cannot be broken down to release glucose, resulting in the production of only small quantities of ATP. People with GSDV are unable to exercise normally, as the lack of ATP affects the functioning of striated muscle.

With reference to the sliding filament model of muscular contraction, suggest why a **lack** of ATP affects the functioning of striated muscle.

* myosin heads do NOT detach from the actin
* myosin heads do NOT hydrolyse ATP
* and hence are NOT activated
* myosin heads don't form cross-bridges
* NO power stroke

[3]

6 **(a)** Describe how tropomyosin and myosin are each involved in the sliding filament model of muscle contraction.

(i) *tropomyosin* ....

* tropomyosin covers the myosin binding site on actin which are exposed when Ca^{2+} bind to troponin. This enables myosin heads to bind to actin to form cross bridges [2]

(ii) *myosin* ....

....

....

....

....

....

....

.... [4]

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(b) Striated muscle is made up of many specialised muscle cells known as muscle fibres or myocytes.

There are two different types of muscle fibre in striated muscle:

- fast twitch muscle fibres that contract quickly, but rapidly fatigue (get tired)
- slow twitch muscle fibres that contract slowly and continue to contract for a long time.

Table 6.1 shows some features of fast twitch and slow twitch muscle fibres.

Table 6.1

feature	fast twitch fibre	slow twitch fibre
respiration	mainly anaerobic	mainly aerobic
glycogen concentration	high	low
capillaries	few	many

Use the information in Table 6.1 to suggest **and** explain **one** advantage of:

(i) the high glycogen concentration in fast twitch fibres

* to supply plenty of glucose
* the ATP produced via anaerobic respiration is minimal

.... [2]

(ii) many capillaries supplying slow twitch fibres.

* to supply enough oxygen
* required for aerobic respiration

.... [2]

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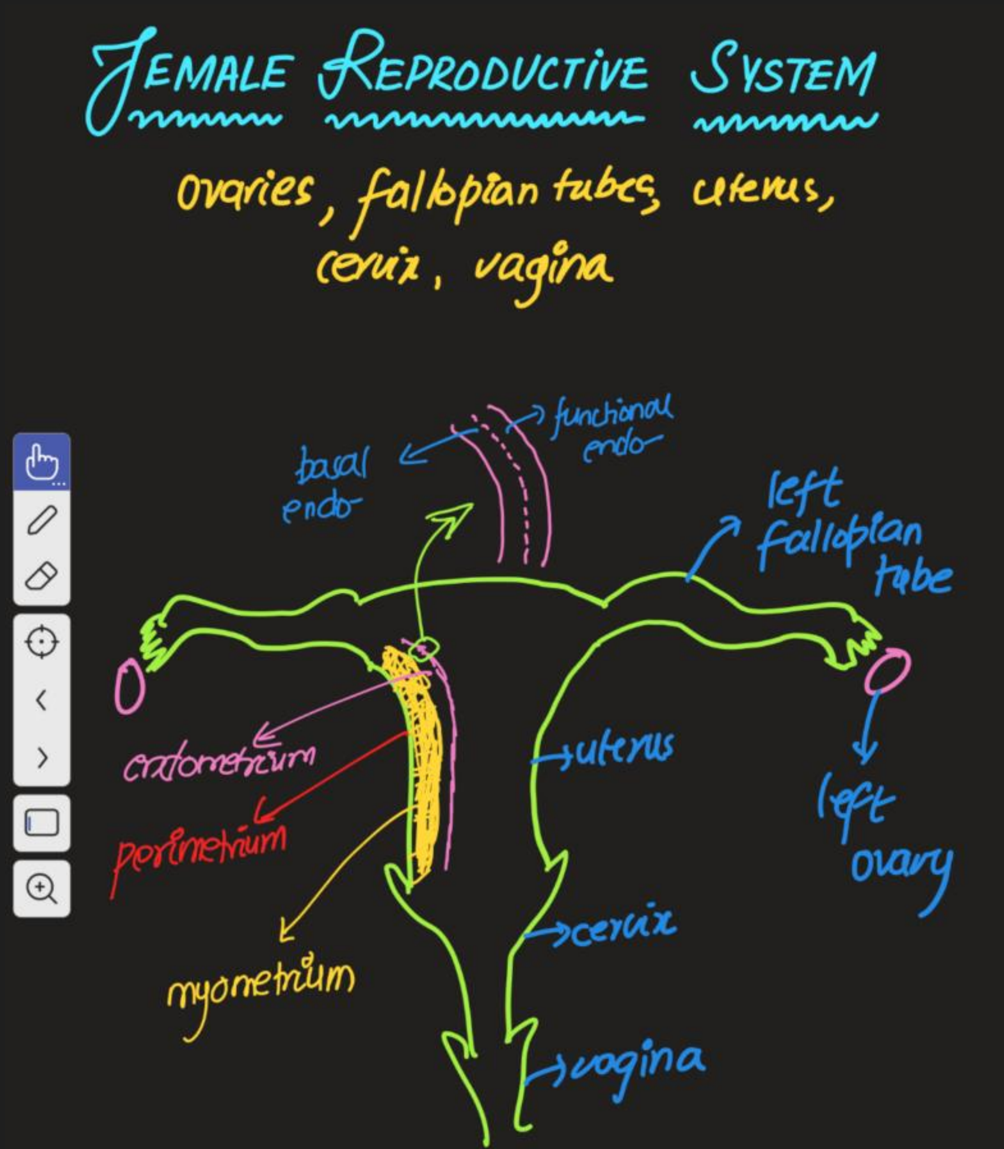
Control & Coordination



With
Mohammad Hussham Arshad, MD

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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Anatomy of the female reproductive system
- Female reproductive hormones
- Structure of the ovary
- Introduction to the menstrual cycle

Video Lecture 12 Slides

Mohammad Hussham Arshad, MD
Biology Department

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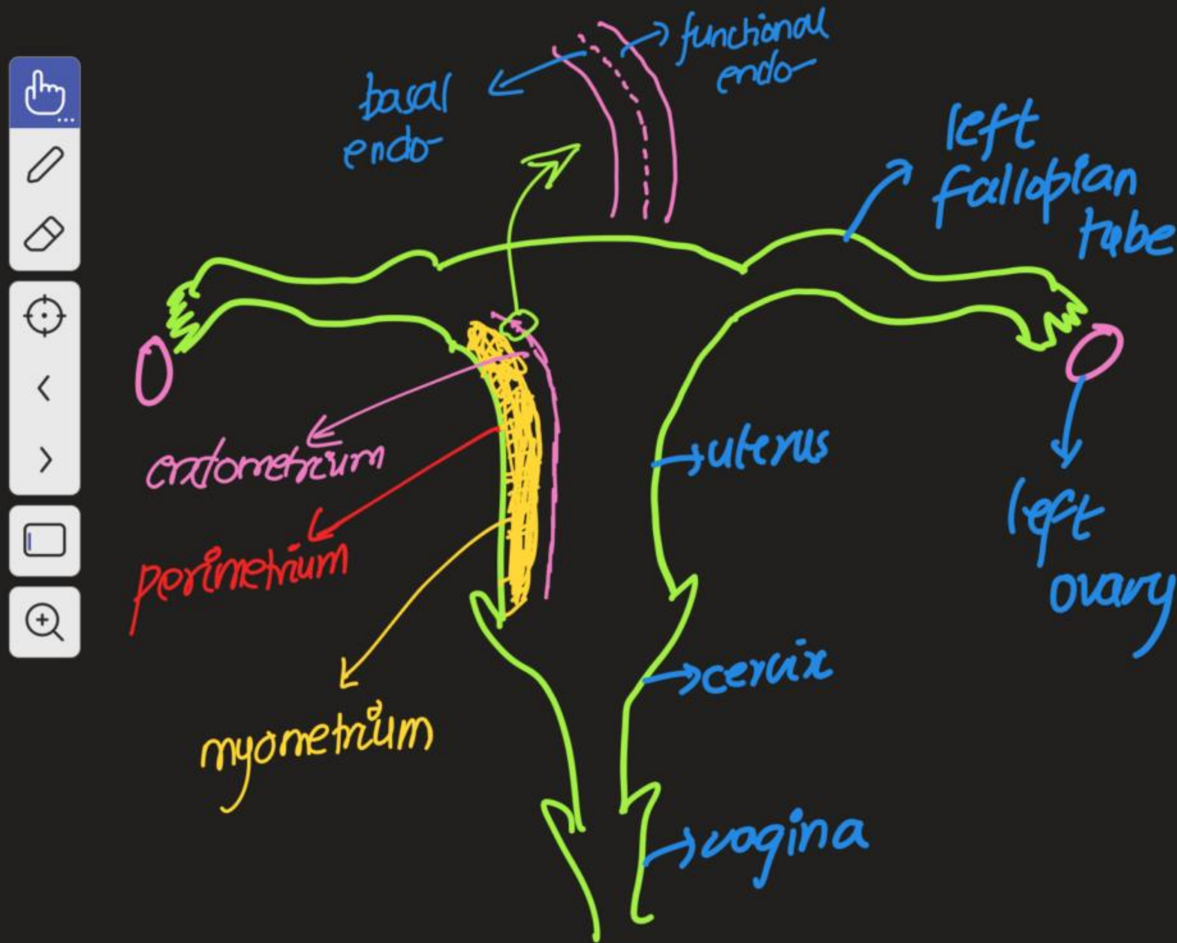
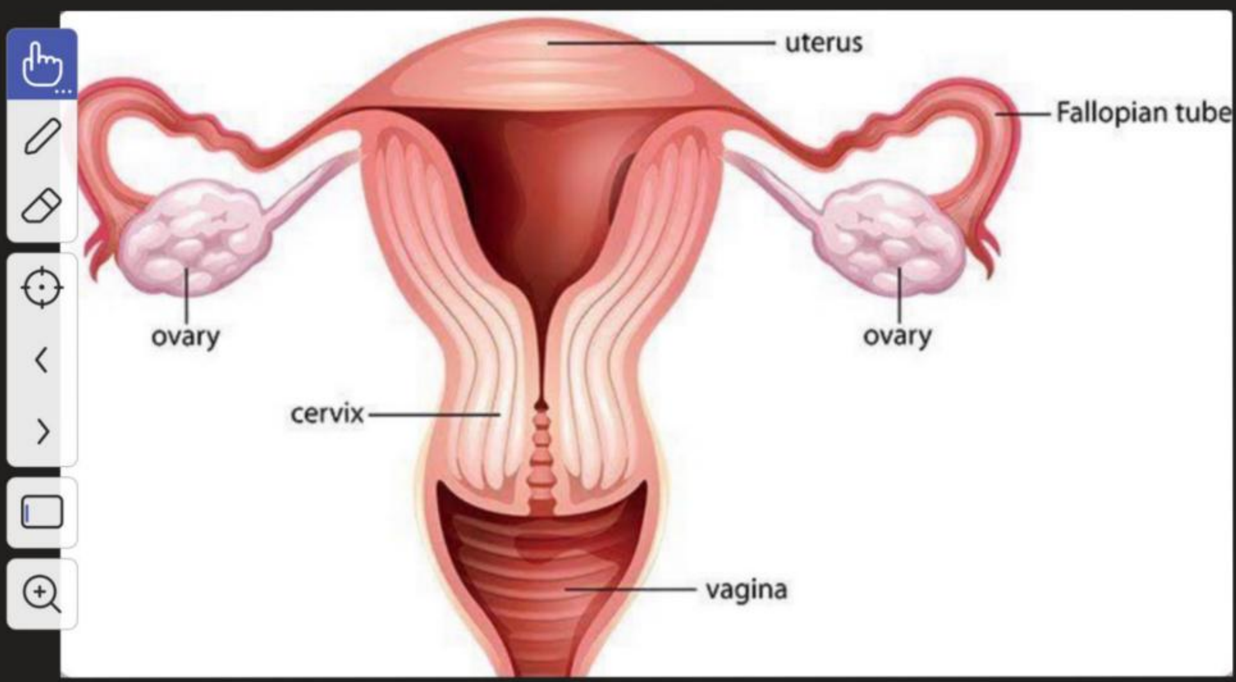
Female reproductive system, Menstrual cycle and Contraception

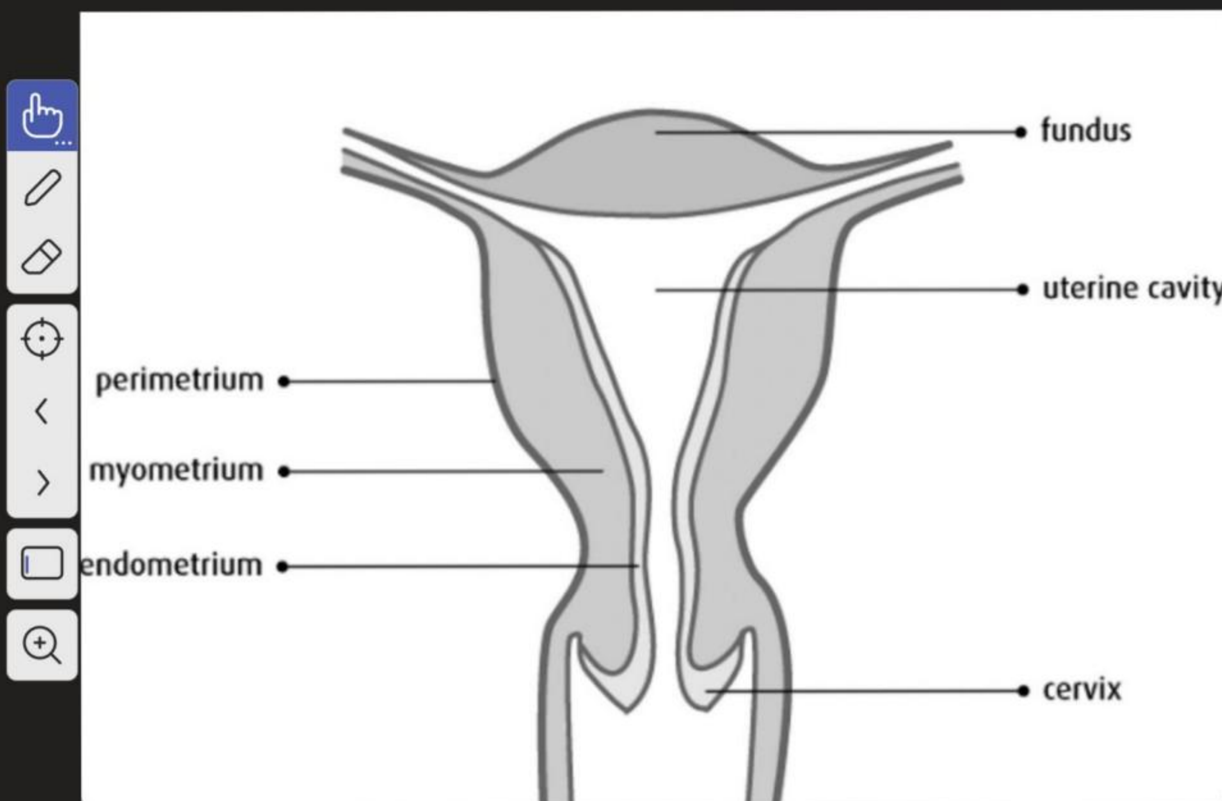
Female reproductive System

Female Reproductive System

ovaries, fallopian tubes, uterus, cervix, vagina




uterus
Fallopian tube
ovary
ovary
cervix
vagina


fundus
uterine cavity
perimetrium
myometrium
endometrium
cervix

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Q1: What's the most common site of fertilisation?

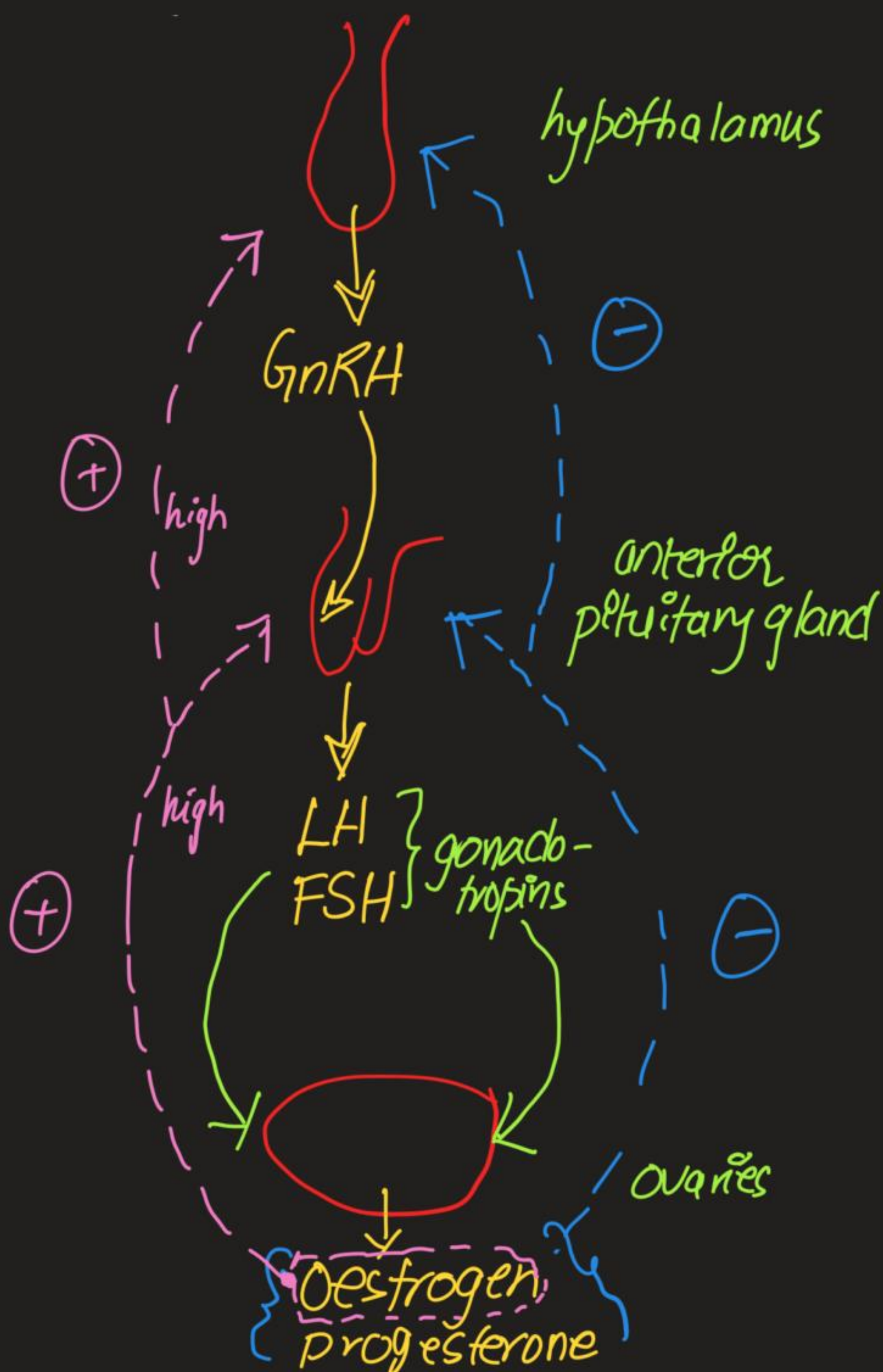
Ans fallopian tube

↳ this is also the most common site of ECTOPIC PREGNANCY

Q2: What's the most common site of implantation?

Ans posterior wall of the uterus

Female Reproductive Hormones



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Female Reproductive Hormones

① Reproductive hormones are produced by the following glands:

a) Hypothalamus which produces hormone GnRH (Gonadotropin releasing hormone)

b) Anterior pituitary gland which prod-uces LH and FSH. LH and FSH are collectively termed as gonadotropins.

c) Ovaries which produce oestrogen and progesterone.

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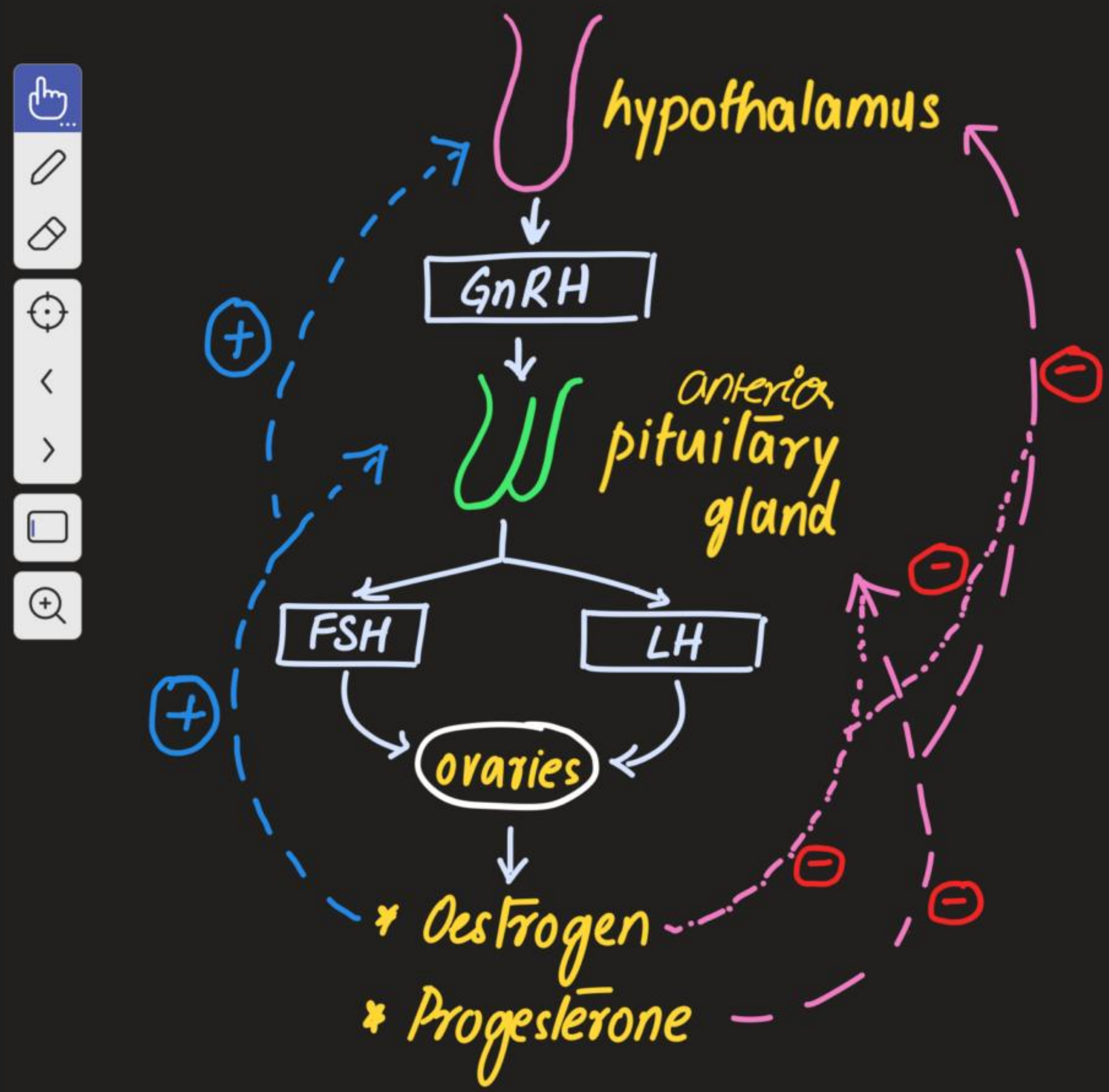
② GnRH, FSH and LH are protein hormones whereas oestrogen and progesterone are steroidal hormones.



LH = Luteinising hormone

FSH = Follicle stimulating hormone

GnRH = GonadoTropin releasing hormone

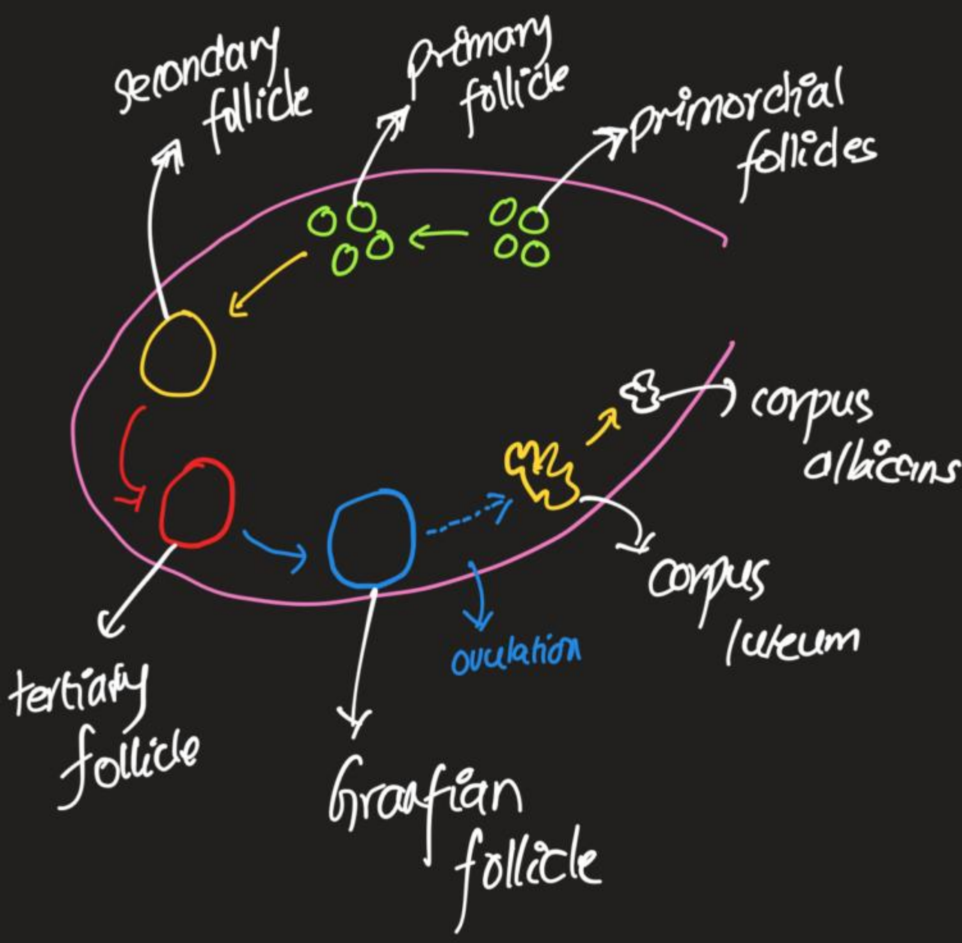
Structure of the ovary

↓

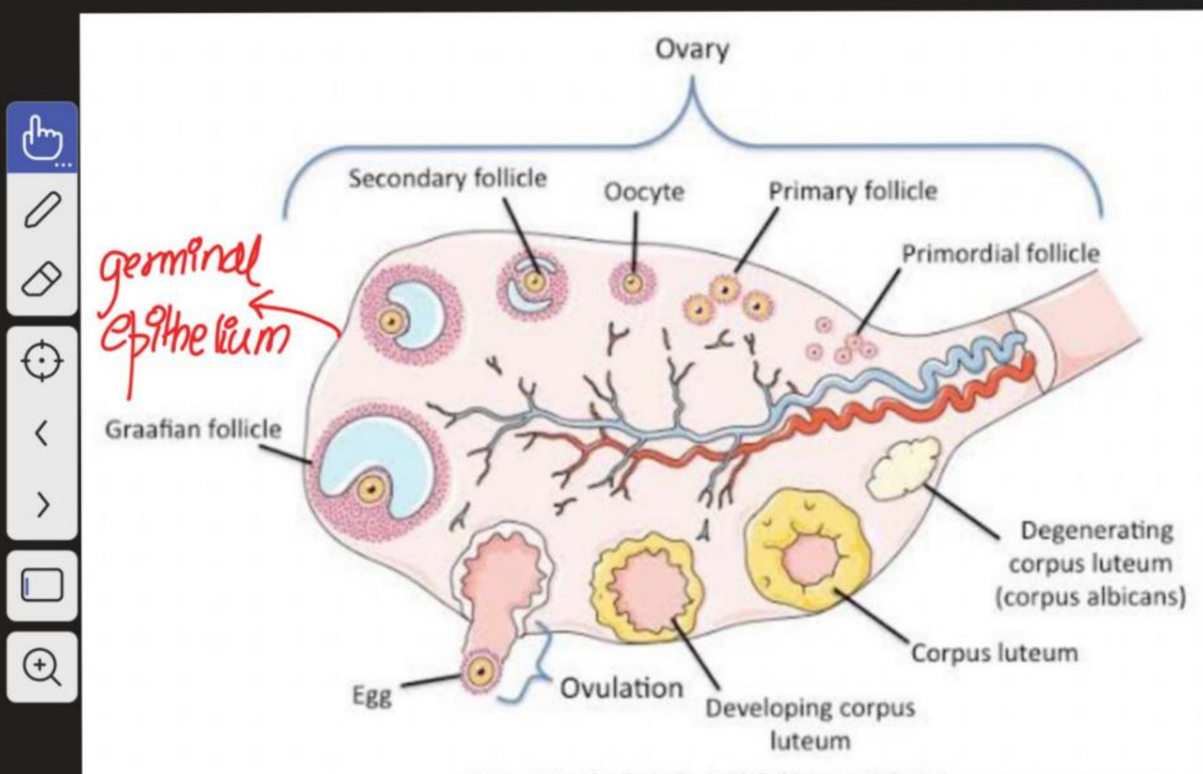
numerous spherical structures at birth known as primordial follicles

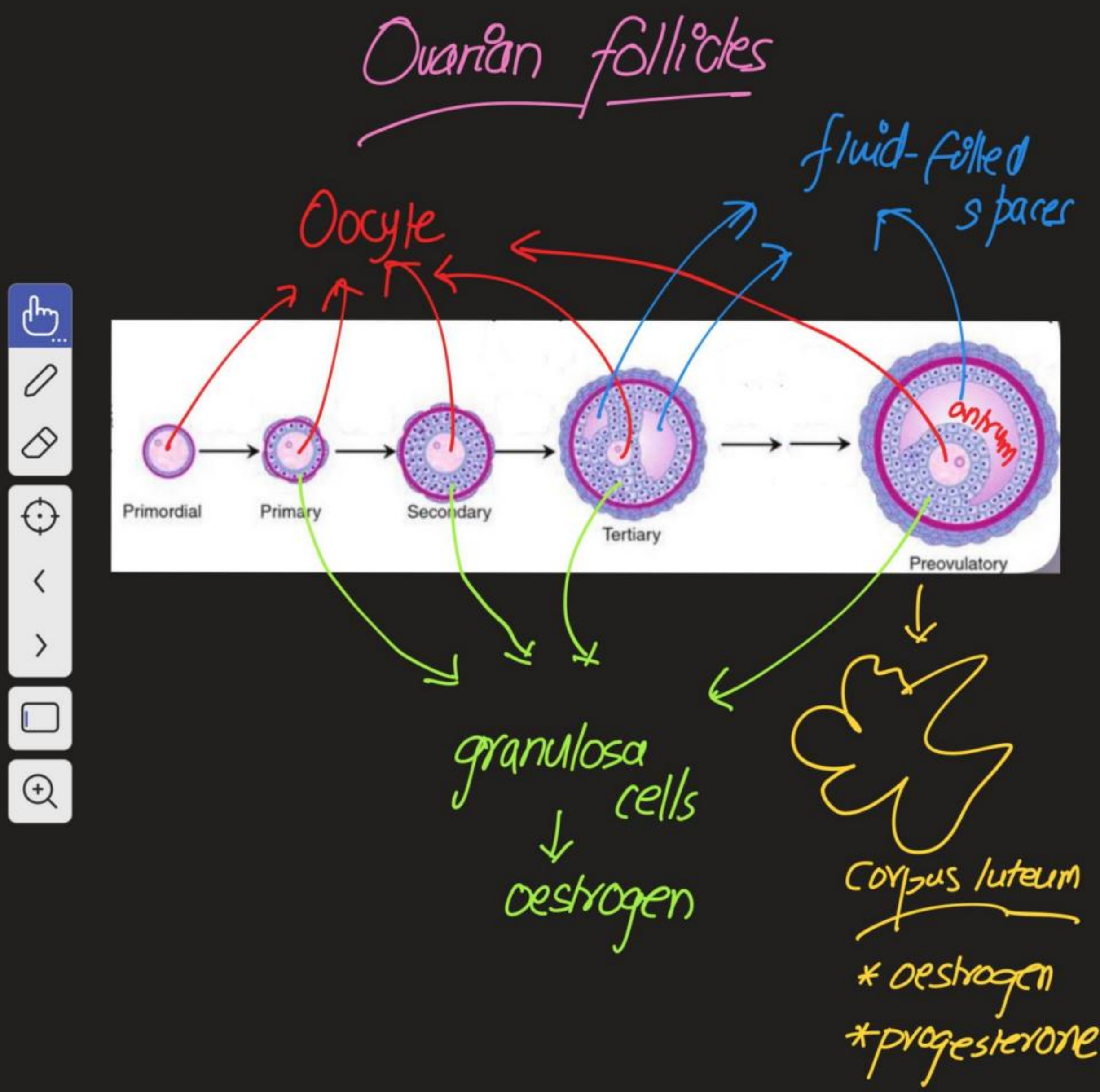
↓

puberty (menarche)



Structure of The ovary




Ovarian follicles
Oocyte
fluid-filled spaces
antrum
Primordial
Primary
Secondary
Tertiary
Preovulatory
granulosa cells
oestrogen
corpus luteum
* oestrogen
* progesterone

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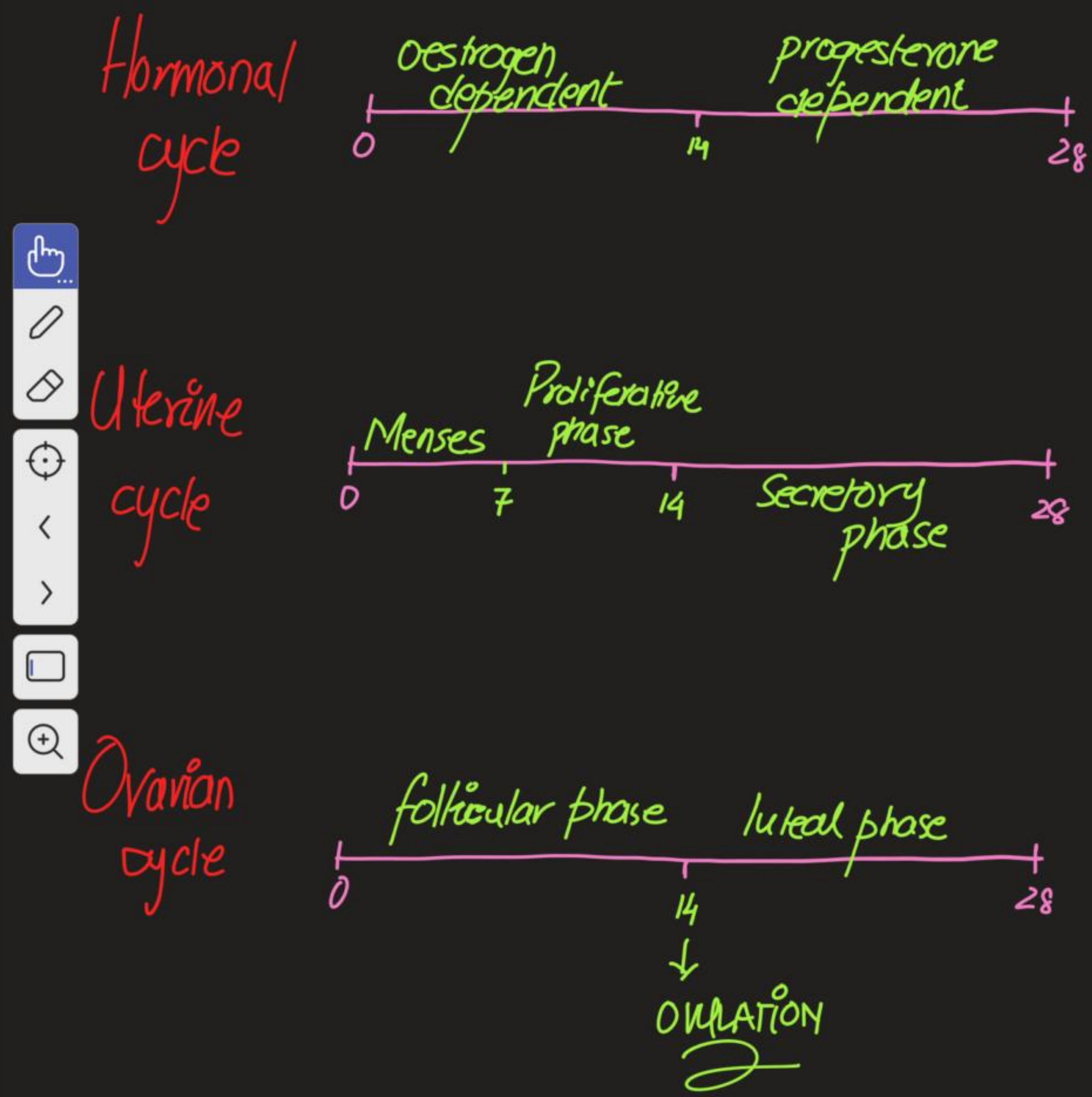
Menstrual cycle



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Menstrual Cycle

* Menstrual cycle refers to the cyclic changes which occur in the uterine endometrium and the ovary due to hormonal changes in the blood.

* The average duration of the human menstrual cycle ranges from 21 to 40 days.

* The onset of menses in the life of a female is termed as menarche.

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* **Menopause** refers to cessation of the menstrual cycle in the life of a female.

* Menstrual cycle can be studied by monitoring the changes that occur in:

a) Uterine endometrium → uterine cycle

b) Ovaries → ovarian cycle

c) Blood hormones → hormonal cycle

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* Phases of the uterine cycle are:

a) Menses

b) Proliferative phase

c) Secretory phase.

* Phases of the ovarian cycle are:

a) Follicular phase

b) Ovulation

c) Luteal phase

* Phases of the hormonal cycle are:

a) Oestrogen dependent phase

b) Progesterone dependent phase

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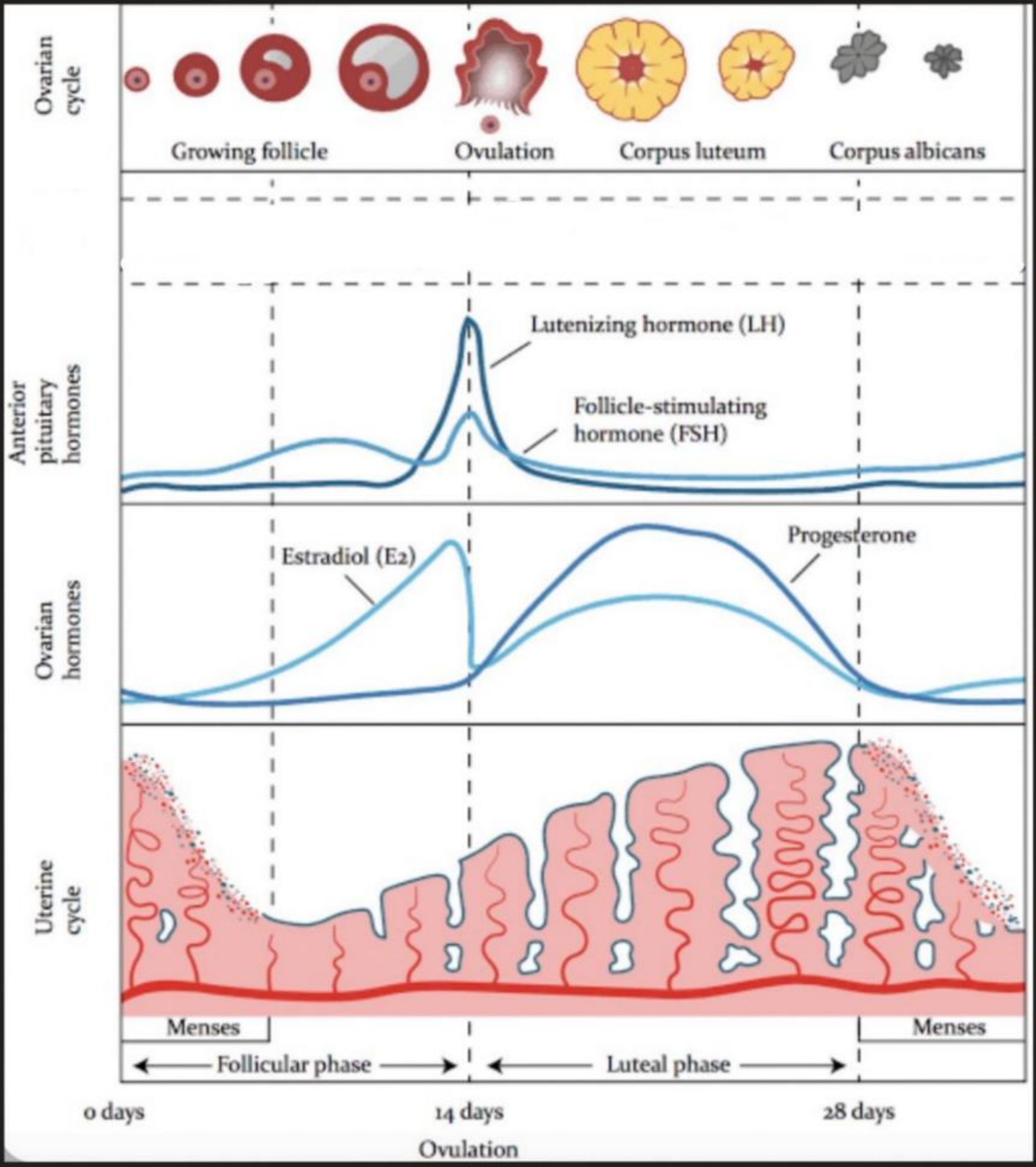
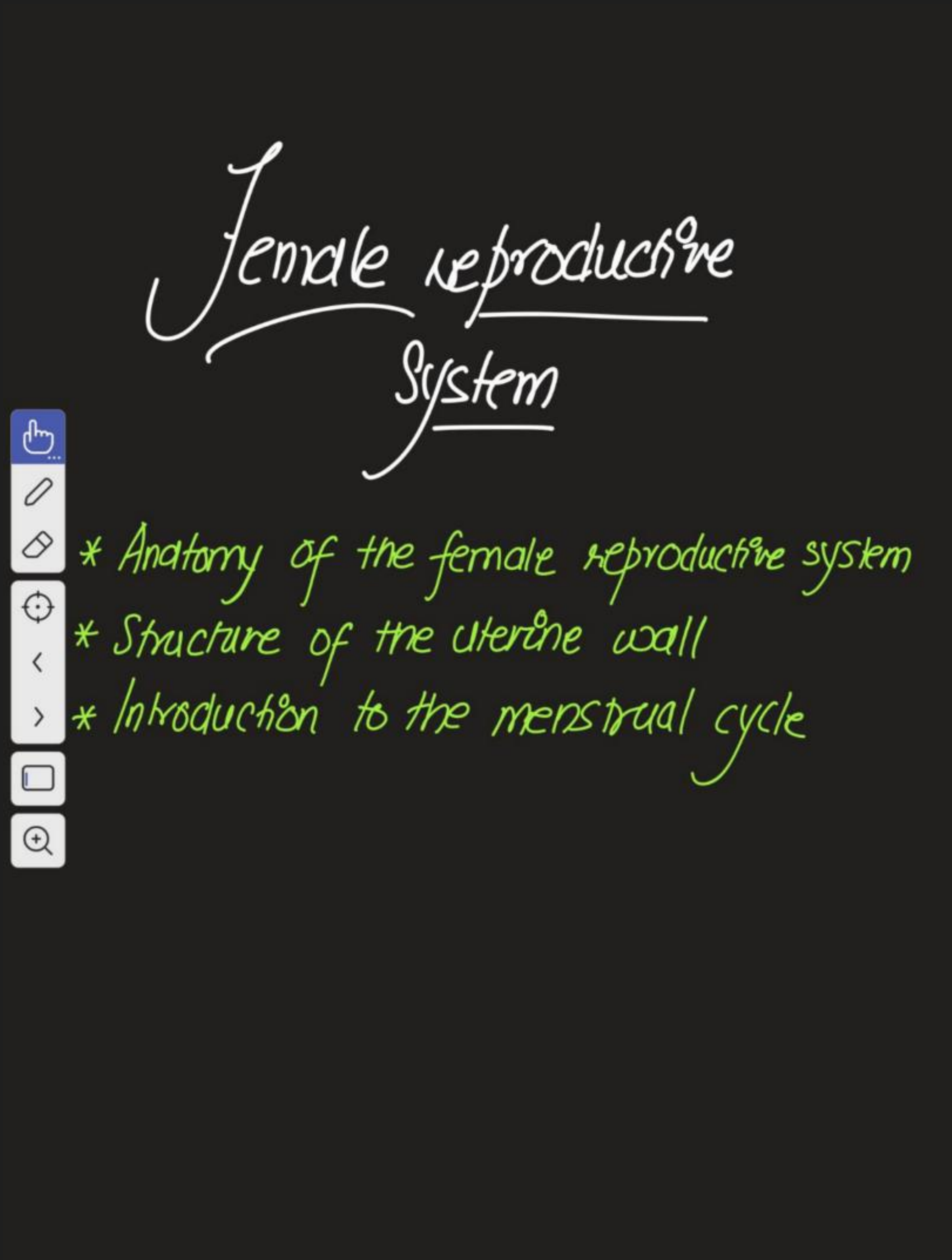
Menstrual cycle



Control & Coordination



With

Mohammad Hussham Arshad, MD

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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Menstrual cycle
- Functions of reproductive hormones
- Contraceptive methods
- Biological basis of contraceptive pills

Video Lecture 13 Slides

Mohammad Hussham Arshad, MD
Biology Department

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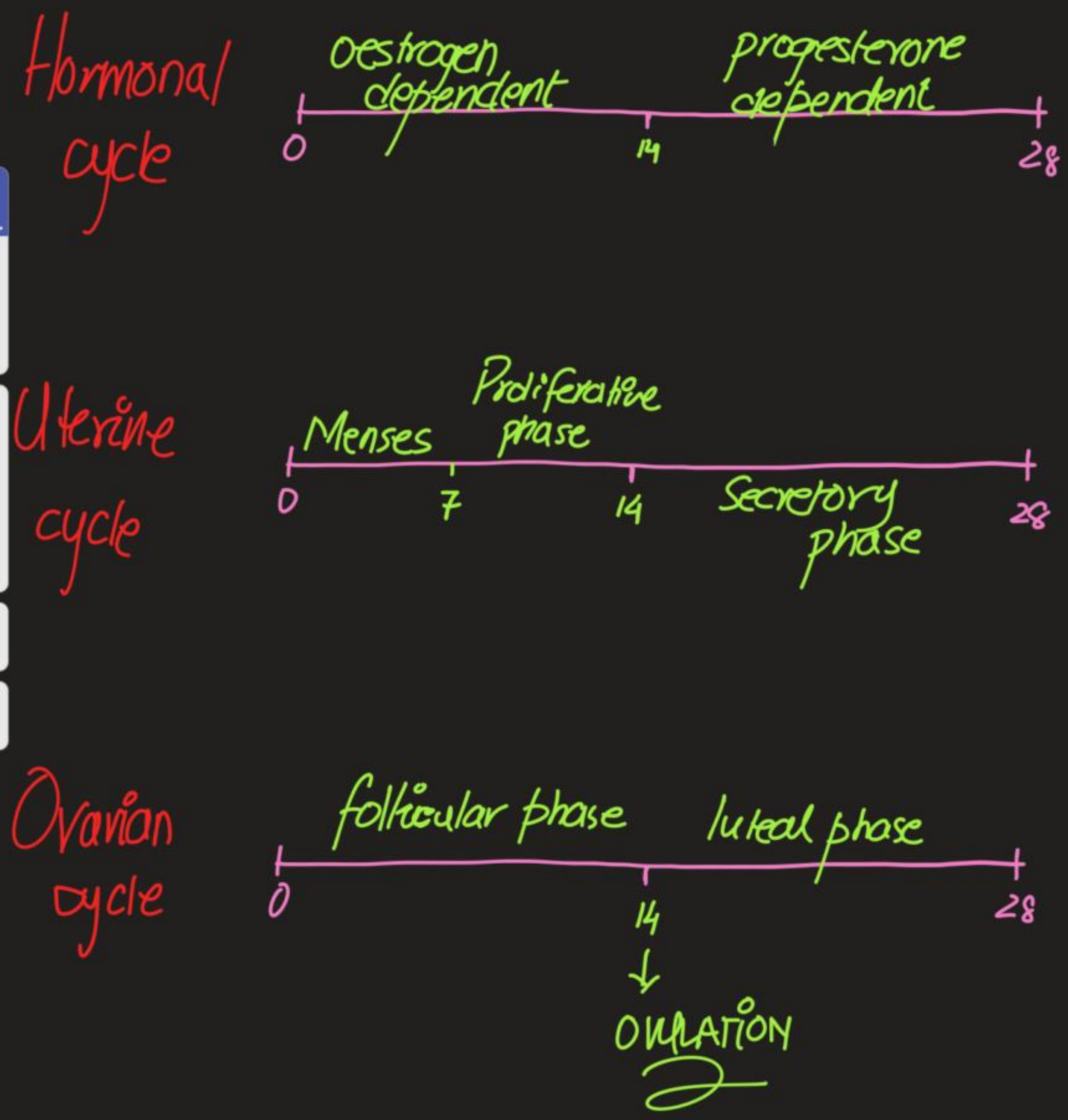
Female reproductive system, Menstrual cycle and Contraception

Female reproductive System

Female reproductive System

* Anatomy of the female reproductive system
* Structure of the uterine wall
* Introduction to the menstrual cycle

Menstrual cycle



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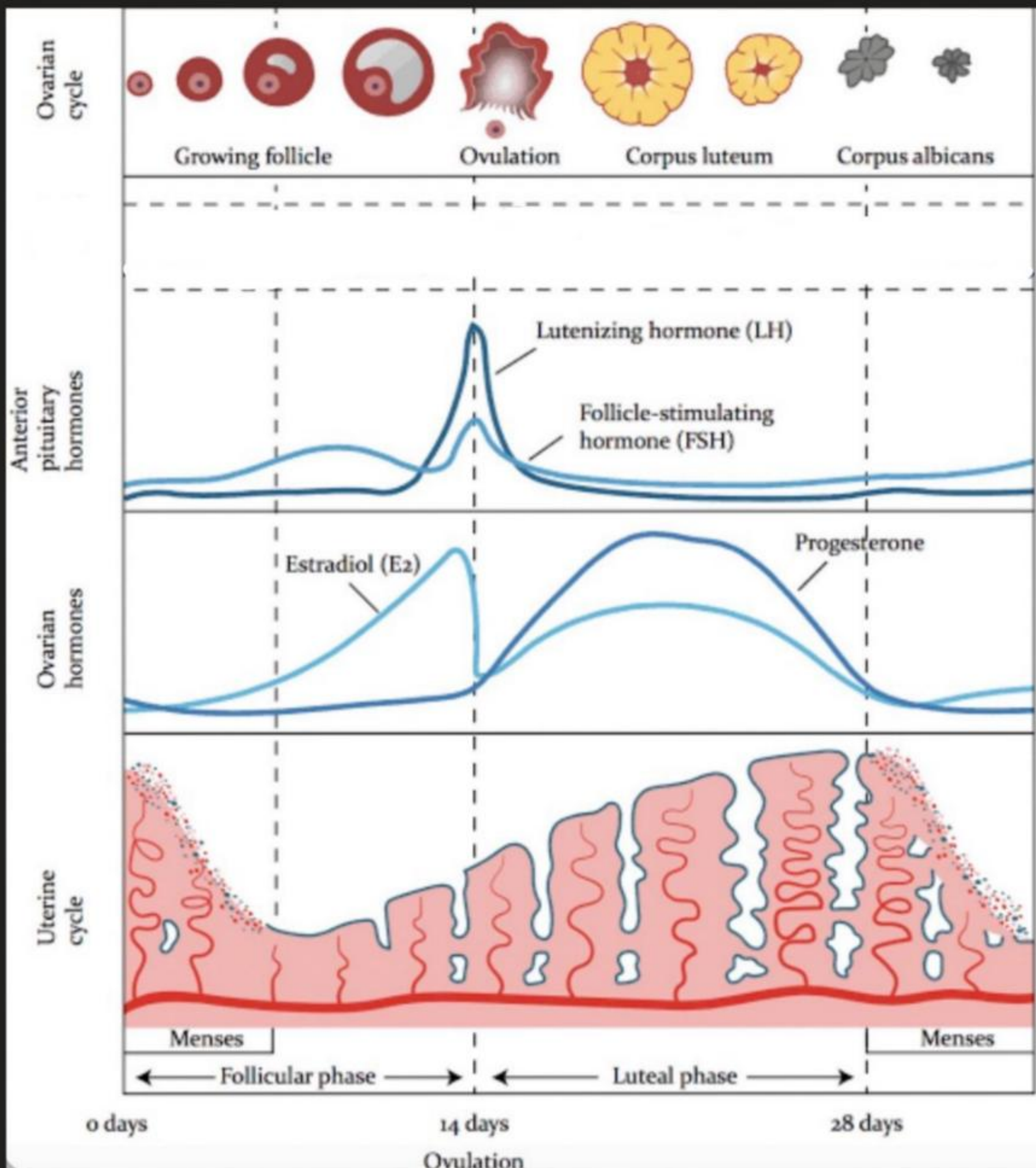
Menstrual cycle



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Sequence of events in a 28-day cycle:

* The onset of menses is Day 0 of the menstrual cycle.

* Drop in the levels of the hormone oestrogen and progesterone causes endometrial lining to shed-off.

* LH and FSH levels rise due to the drop in the levels of oestrogen and progesterone.

* FSH acts on the primary follicles within the ovaries promoting growth

of the follicles.

* One of the follicles will mature to form a Graafian follicle.

* The granulosa cells within the follicles produce the hormone oestrogen which exerts a -ve feedback effect on the anterior pituitary decreasing the release of LH and FSH.

* Oestrogen acts on the endometrial lining promoting proliferation of the

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endometrial cells.

* By Day 14, the endometrium lining thickens to 3-4 mm.

* High levels of oestrogen exert a +ve feedback effect on the anterior pituitary leading to the LH surge.

* LH surge causes ovulation on Day 14 in a 28 day cycle.

* LH surge also promotes leuteinisation of the Graafian follicle to form the

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corpus luteum.

* Corpus luteum is a granular endocrine body with excess of lipids which gives it a yellow colouration (thus yellow body).

* Cells of the corpus luteum secrete the hormones oestrogen and progesterone. Progesterone is produced in much higher amounts than oestrogen.

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* Progesterone further thickens the endometrial lining and promotes the growth of the endometrial glands to produce secretions rich in glycogen and lipids.
* If fertilisation does not occur, the corpus luteum degenerates to form a white body known as corpus albicans.
* Drop in the levels of progesterone & oestrogen due to degeneration of corpus luteum leads to vasoconstriction of the

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endometrial blood vessels. This causes ischaemic necrosis of the endometrial cells (shedding of the endometrial lining).

+ This marks the onset of next menstrual cycle.

Functions of reproductive hormones

Functions of Hormones

① GnRH:

① Site of release: Hypothalamus

② Target site: Anterior pituitary gland

③ Function: GnRH promotes the release of FSH and LH from the anterior pituitary gland.

② FSH:

① Site of release: Anterior pituitary gland

② Target site: Granulosa cells of the follicles (follicle cells)

③ Function: a) * FSH binds to its receptors on the granulosa cells and promotes growth of follicles (folliculogenesis). b) * Stimulates the granulosa cells to produce & secrete oestrogen.

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③ LH:

① Site of release: Anterior pituitary gland

② Target site: Granulosa cells (follicle cells) and cells of corpus luteum.

③ Function: a)* LH promotes growth of follicles

b)* LH surge causes ovulation.

c)* LH surge leads to formation of corpus luteum.

d)* LH stimulates the corpus luteum to produce & secrete oestrogen & progesterone.

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(4) Oestrogen:

(1) Site of release: Granulosa cells & corpus luteum

(2) Target site: Uterine endometrium, the cervix, anterior pituitary gland & hypothalamus.

(3) Function: a) * Oestrogen acts on the endometrial lining to stimulate repair of the endometrium by proliferation of endometrial cells.

b) * Oestrogen promotes the formation of blood vessels within the endometrium.

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c) *Oestrogen causes thinning of the cervical mucus so that the sperms can easily ascend up the female reproductive tract.

d) *At low to moderate concentration, it exerts a -ve feedback effect on the hypo-thalamus and the anterior pituitary.

e) *At high concentrations, oestrogen exerts a +ve feedback effect on the anterior pituitary which leads to LH & FSH surge.

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⑤ Progesterone:

① Site of release: Corpus luteum

② Target site: Uterine endometrium, cervix, anterior pituitary gland and hypothalamus.

③ Function: a) * Progesterone promotes further thickening and maintenance of the endometrial lining.

b) * It promotes the formation and spiralisation of blood vessels within the endometrium.

c) * It stimulates the endometrial glands to produce secretions rich in glycogen & lipids. This prepares endometrium for implantation.

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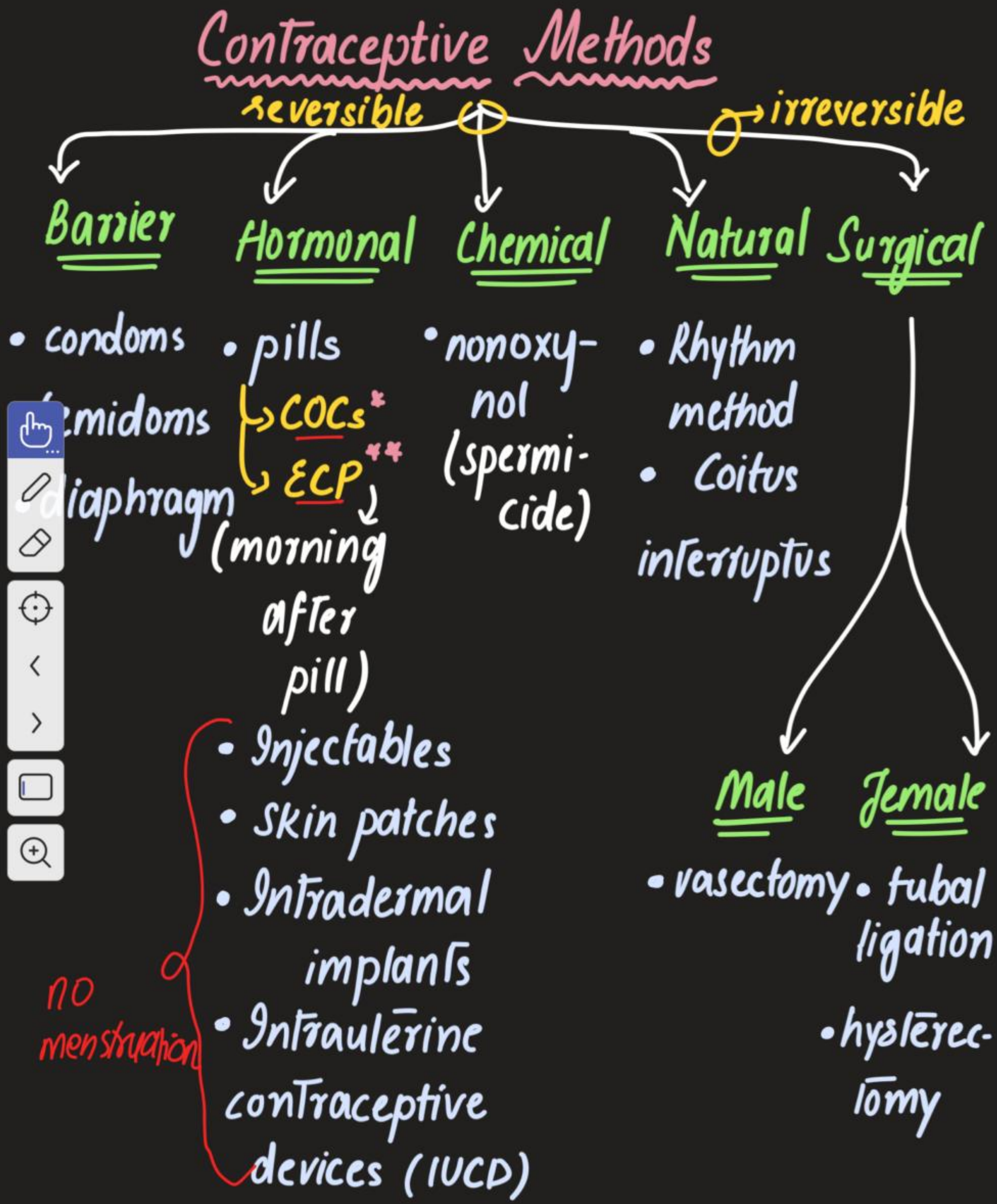
d) * It causes thickening of the cervical mucus.

e) * Progesterone exerts a -ve feedback effect on the hypothalamus and the anterior pituitary.

Contraceptive Methods


Contraceptive Methods
reversible
irreversible
Barrier
Hormonal
Chemical
Natural
Surgical
• condoms
• femidoms
• diaphragm
• pills
COCs *
ECP **
(morning after pill)
• Injectables
• Skin patches
• Intradermal implants
• Intrauterine contraceptive devices (IUCD)
no menstruation
• nonoxynol (spermicide)
• Rhythm method
• Coitus interruptus
Male
Female
• vasectomy
• tubal ligation
• hysterectomy

*combined oral contraceptives

**emergency contraceptive pills

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Oral contraceptive Pills:

* Oral contraceptive pills is the most common method of offering hormonal contraception.

* Oral contraceptive pills are available in the following two formulations:

a) Combined (COCs) which include oestrogen and progesterone.

b) Morning after pill (ECP) (emergency contraceptive pill) which only includes progesterone

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Combined Oral Contraceptives (COCs)

* The hormones (oestrogen + progesterone) present in COCs are synthetic and hence have a longer half-life.
* OCP's prevent ~~conception~~ pregnancy in the following ways (biological basis):

i) Oestrogen and progesterone present within the pills exert a negative feedback effect on the anterior pituitary gland which reduces the release of the gonadotropins 'LH and FSH'. Drop in FSH prevents the formation of Graafian follicle. Drop in LH prevents ovulation.

ii) Progesterone and oestrogen in combination within these pills causes thinning of the endometrial lining which makes the endometrium unsuitable for implantation.

iii) OCPs cause thickening of the cervical mucus which interrupts the ascension of the sperms into the female reproductive tract (leads to prevention of pelvis infections but not as much as barrier methods).

COCs routine

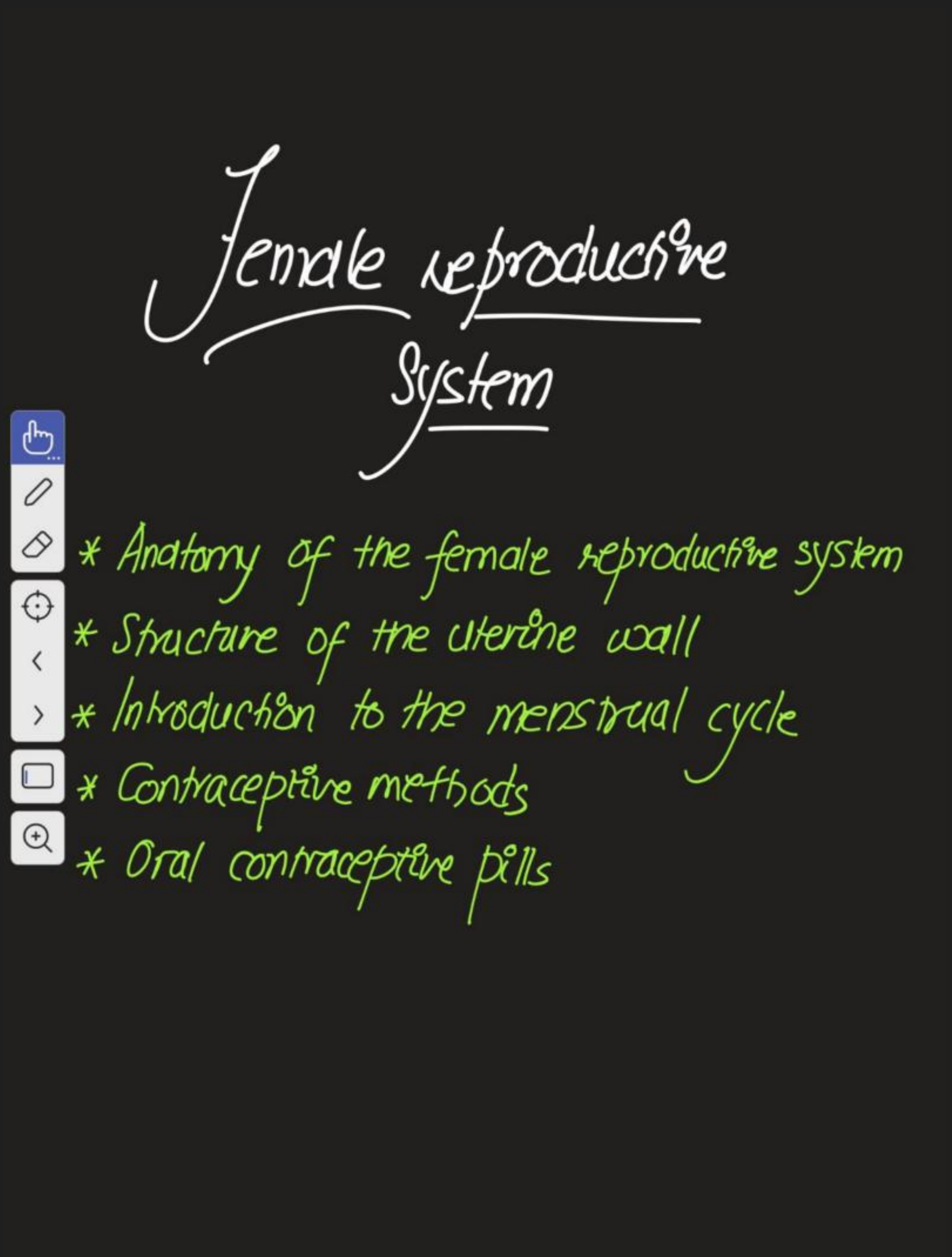
Morning after pill

* Morning after pill is an emergency contraceptive pill which can be taken within 72 hours following intercourse. It is advised in the following cases:

a) Rape victims b) Females who skip an oral contraceptive pill c) woman who did not take precautions to prevent pregnancy.

* Morning after pills contain high dose of progesterone and prevent pregnancy by;
  - preventing fertilisation
  - preventing implantation

Control & Coordination



With

Mohammad Hussham Arshad, MD

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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Practice Questions: Menstrual cycle & contraceptive pill

Video Lecture 14 Slides

Mohammad Hussham Arshad, MD
Biology Department

Female reproductive System

* Anatomy of the female reproductive system
* Structure of the uterine wall
* Introduction to the menstrual cycle
* Contraceptive methods
* Oral contraceptive pills


Questions

Q1.

6 (a) Fig. 6.1 shows the concentration of two hormones, oestrogen and progesterone, in a woman's blood during one menstrual cycle.

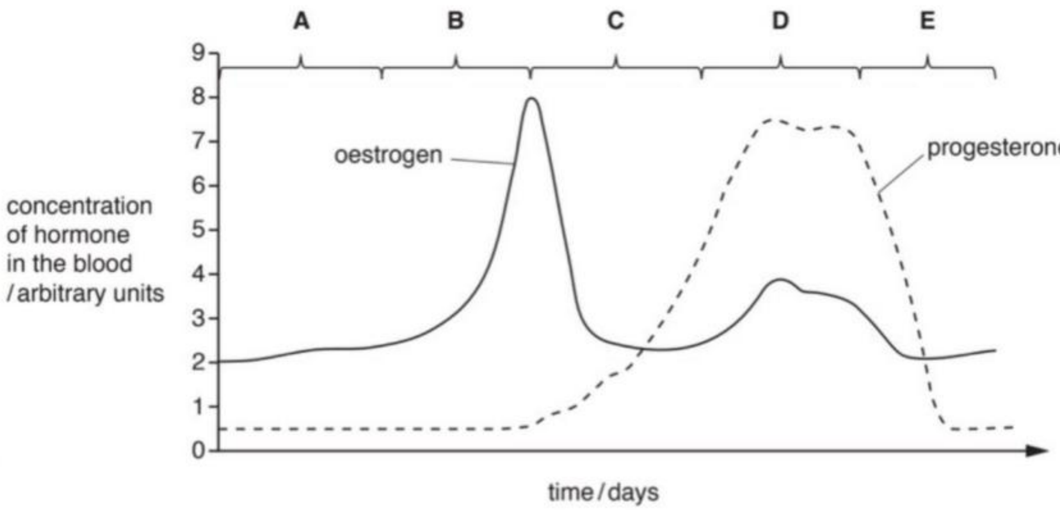


Fig. 6.1

(i) With reference to Fig. 6.1, state the letter of the stage of the cycle during which ovulation occurs.

C ....[1]

(ii) State how Fig. 6.1 shows that the woman did not become pregnant during this cycle.

b/c the concentration of oestrogen and progesterone decreases. ....[1]

(iii) Name the ovarian structure that secretes progesterone after ovulation.

corpus luteum ....[1]

(iv) State the role of progesterone during stage **D**.

* maintenance of the endometrium ....[1]

(b) The combined contraceptive pill contains oestrogen and progesterone.

Explain how this combined contraceptive pill works to prevent pregnancy.

* negative feedback on the anterior pituitary
* which reduces the secretion of LH and FSH
* decrease in FSH prevents the formation of Graafian follicle
* decrease in LH prevents ovulation
* thinning of the endometrium → makes it unsuitable for implantation
* thickening of the cervical mucus

[4]

Q2.

8 **(a)** In mammals, the nervous system and the endocrine system coordinate responses to the changes in internal and external environments.

Complete Table 8.1 to indicate the differences between the nervous system and the endocrine system.

Table 8.1

feature	nervous system	endocrine system
method of communication	electrical	chemical
method of transmission	neurones	blood
transmission speed	rapid	slower
duration of effect	short-lasting	long-lasting

[4]

(b) Fig. 8.1 shows the changes in the concentration of hormones in the blood during the menstrual cycle.

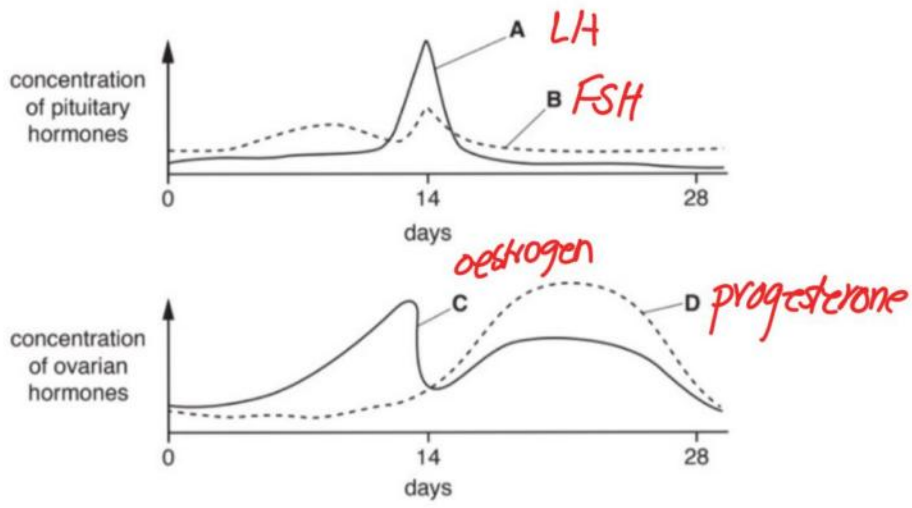


Fig. 8.1

With reference to Fig. 8.1, match hormones **A**, **B**, **C** or **D** to the correct statements 1 to 4.

Each hormone may be used once, more than once or not at all.

1 made by the corpus luteum .... D (and C)

2 stimulates the repair of the endometrium C

3 maintains the endometrium .... D

4 stimulates ovulation .... A

[4]

(c) Outline the biological basis for contraceptive pills containing oestrogen and progesterone.

↓ how the pills achieve contraception

.... [5]

Q3.

6 (a) Fig. 6.1 shows the concentration of four hormones in a woman's blood during one menstrual cycle.

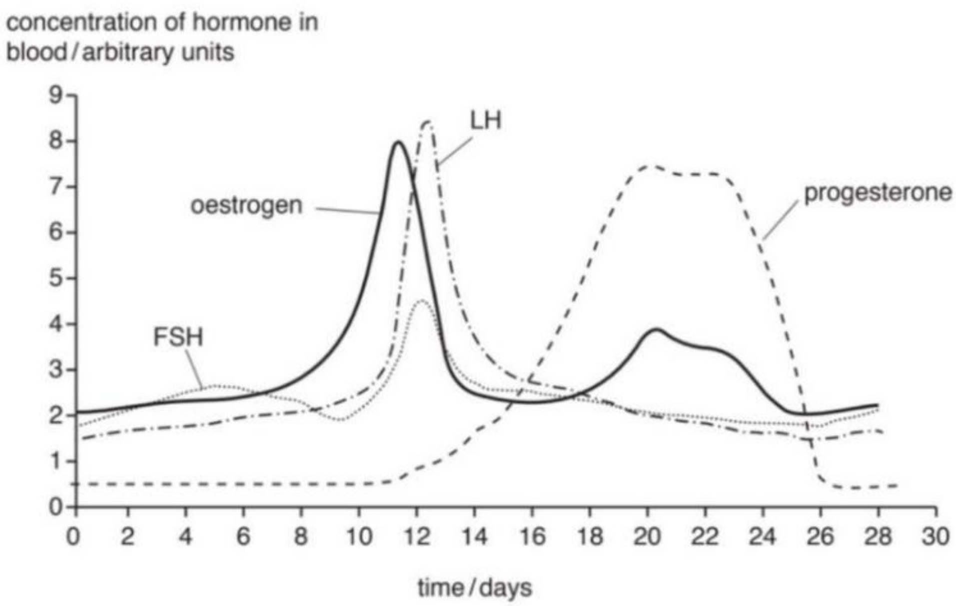


Fig. 6.1

(i) With reference to Fig. 6.1, explain why there is a large increase in LH at around day 12.

b/c of high concentration of oestrogen

....[1]

(ii) State how Fig. 6.1 shows that the woman did not become pregnant during this cycle.

b/c the concentration of oestrogen and prog-
esterone decreases ....[1]

(b) The combined oral contraceptive pill contains oestrogen and progesterone.

(i) Explain how this combined contraceptive pill works to prevent pregnancy.

how the contraceptive pill work / biological basis

....[4]

(ii) Suggest why some women take the combined contraceptive pill for just the first 21 days of their cycles.

to allow menstruation to occur

....[1]

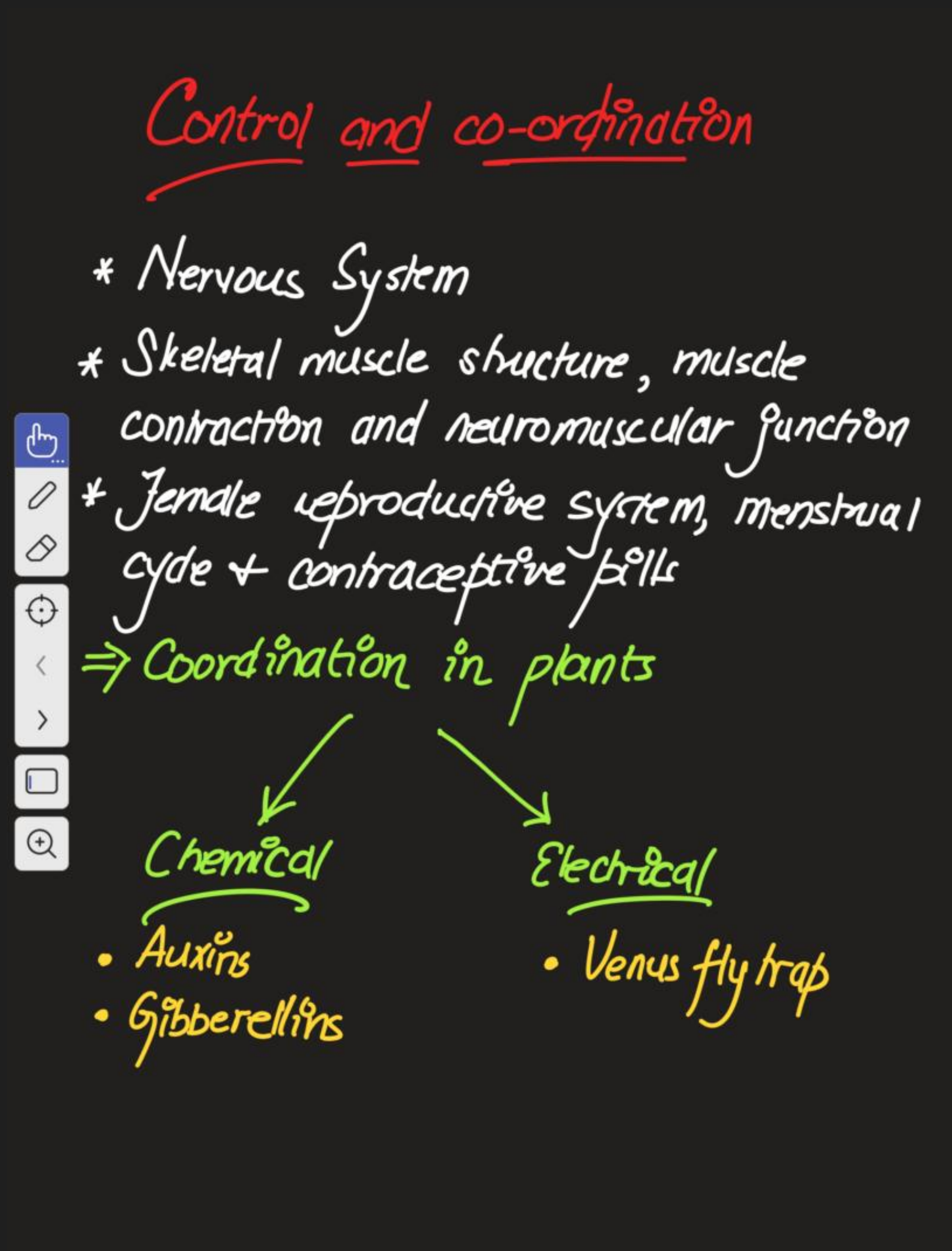
(iii) Some women have a contraceptive device inserted under the skin. This releases hormones into the blood and can last for up to three years.

Suggest **one** advantage of using such a device rather than taking contraceptive pills.

* there will be no menstruation

....[1]

Control & Coordination



With
Mohammad Hussham Arshad, MD

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ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Control & coordination in plants
- Auxins and cell elongation
- Auxins and apical dominance
- Gibberellins and seed germination

Video Lecture 15 Slides

Mohammad Hussham Arshad, MD
Biology Department

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Control and co-ordination

* Nervous System
* Skeletal muscle structure, muscle contraction and neuromuscular function
* Female reproductive system, menstrual cycle + contraceptive pills

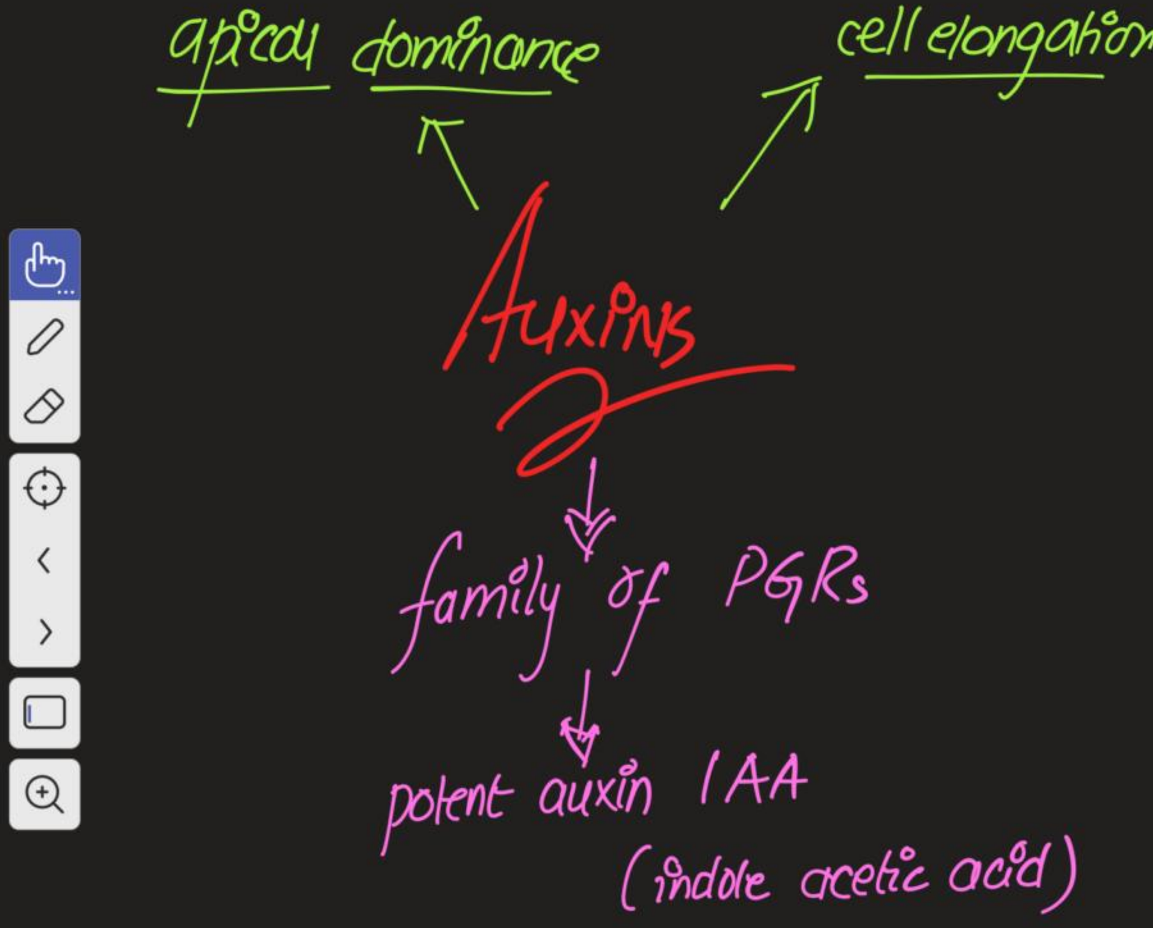
⇒ Coordination in plants

Chemical

- Auxins
- Gibberellins

Electrical

- Venus fly trap


apical dominance
cell elongation
Auxins
family of PGRs
potent auxin IAA
(indole acetic acid)

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Auxins:

The Term auxin is derived from the Greek word auxein which means To grow. Auxins are plant hormones. The most important auxin produced by plants is indole-3-acetic acid (IAA)

* It plays an important role in a number of plant activities, including:

→ phototropism

→ apical dominance

→ cell elongation

* You are only expected to know the role of auxins in cell elongation and apical dominance.

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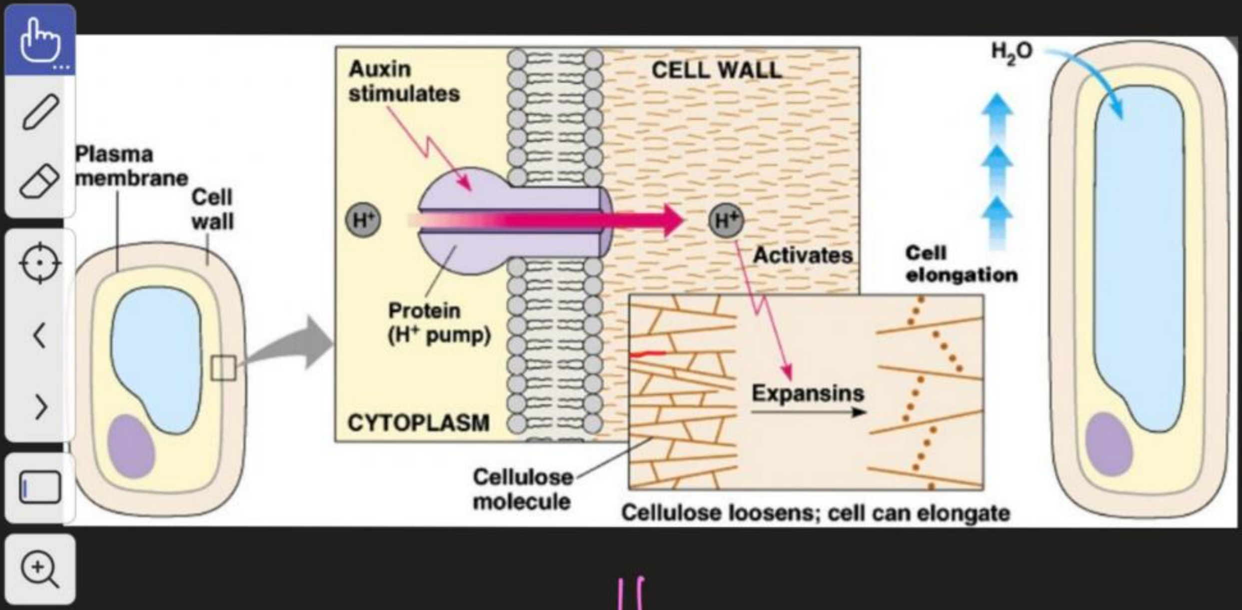
Auxins and cell elongation



⇓

ACID-GROWTH HYPOTHESIS

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Auxins and cell elongation:

Q: How do auxins promote cell elongation?

Ans: 1. Auxins promote cell elongation according to the acid growth hypothesis (figure above).

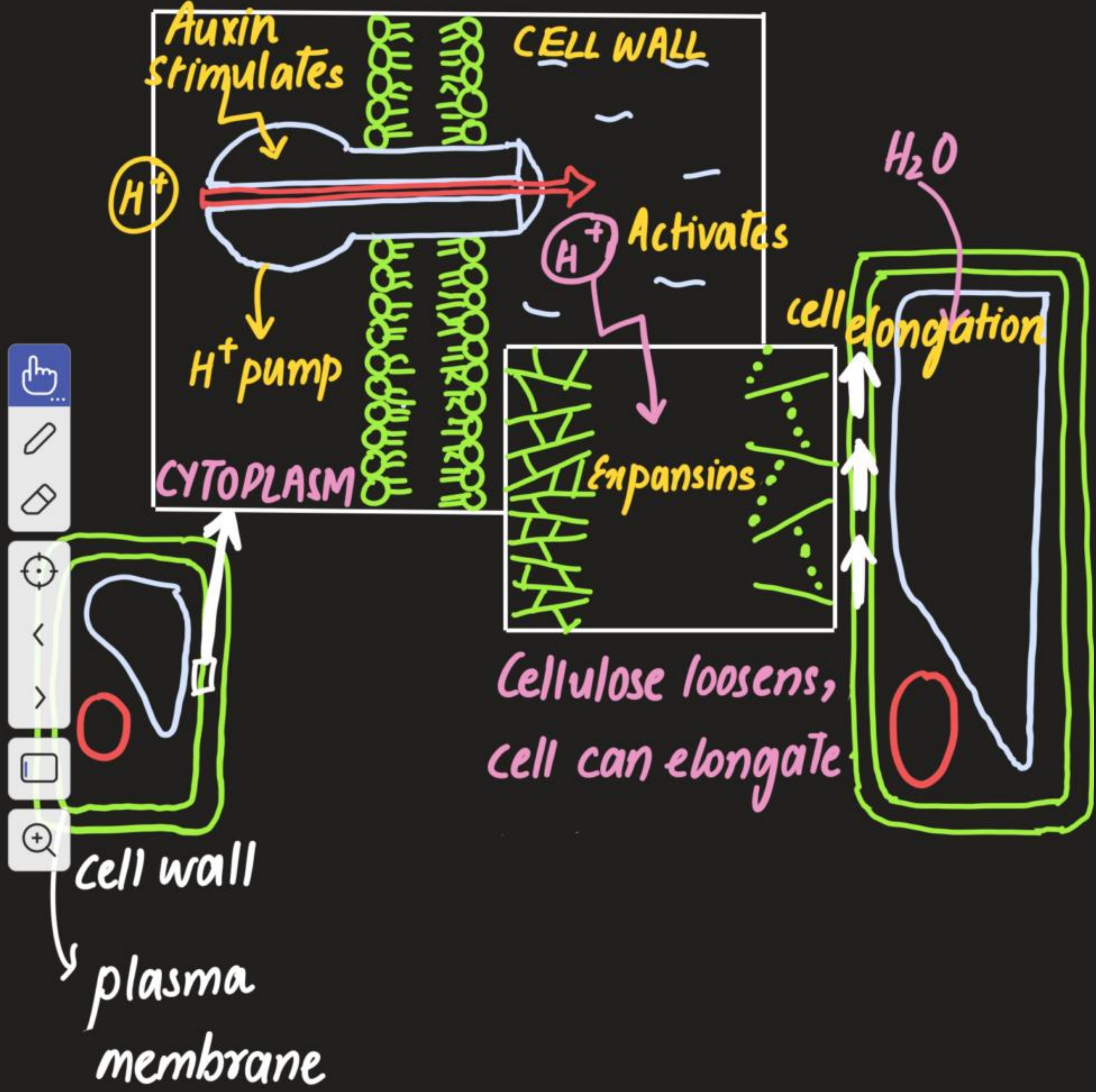
2. Auxins bind to their receptors and stimulate proton pumps in the cell surface membrane.

3. H^+ are actively pumped to the cell wall making the cell wall acidic.

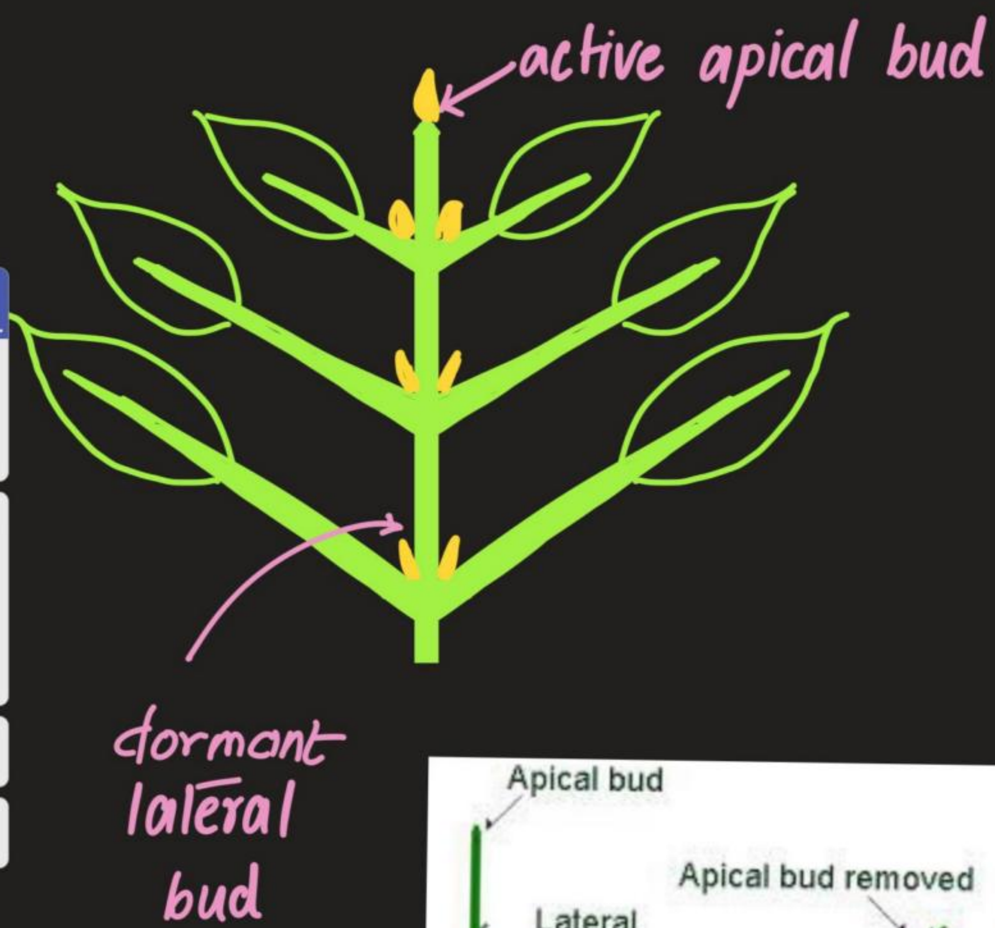
4. Low pH of the cell wall activates a group of proteins known as expansins.

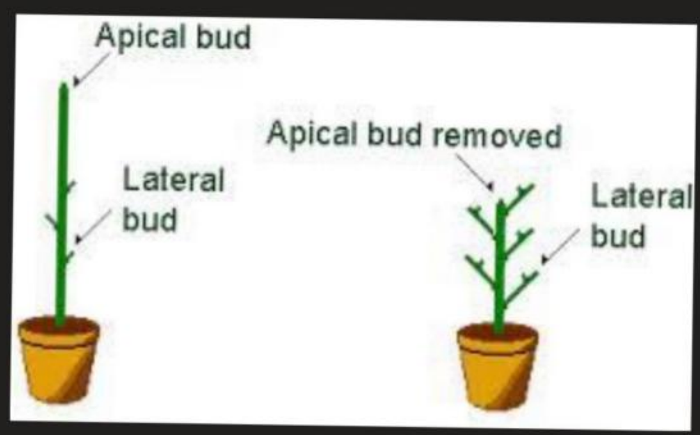
5. Expansins loosen the linkages between cellulose microfibrils making the cell wall more elastic.

6. Water enters the plant cells thereby increasing the turgor pressure and causing cell elongation.


Auxin
Stimulates
CELL WALL
H+
H+ pump
CYTOPLASM
H+ Activates
Expansins
H2O
cell elongation
Cellulose loosens,
cell can elongate
cell wall
plasma
membrane

Auxins and apical dominance





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Auxins and apical dominance:

* Growth of the shoot apex (apical bud) usually inhibits the development of the lateral buds on the stem beneath.
* This phenomenon is called apical dominance.

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Q: Describe the part played by auxins in apical dominance of a shoot?

1. Auxins are synthesized in the apical bud.
2. diffuse down the stem from cell to cell or by mass flow in phloem.
3. Stimulates cell elongation (NOT-enlargement)
4. Auxins bind to their receptors and stimulate proton pumps in the cell membrane.

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5. H^+ are pumped into the cell wall making it more acidic which activates a group of proteins known as expansins.

6. Expansins loosen the linkages between cellulose microfibrils enabling cell elongation.

7. Auxins inhibit lateral buds.

8. Shoot therefore grows upwards.

9. Auxins interact with other PGRs, like cytokinins and abscissic acid.

10. Cytokinins are antagonistic to auxins.

11. Abscissic acid enhances actions of auxins.

Gibberellins

↓

family of PGRs

↓ derivatives of Gibberellic acids (GA)

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Gibberellins:

* Gibberellins are derivatives of gibberellic acid.
* They are natural plant hormones and promote:
  - → flowering
  - → stem elongation, and
  - → germination of seeds
* There are about 100 different gibberellins but gibberellic acid (GA_1) is the most commonly used form.

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* Gibberellin synthesis inhibitors are extensively used in grain production to keep stems artificially short; shorter and thicker stems provide better support and resist weather conditions better too.

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Gibberellins and seed germination

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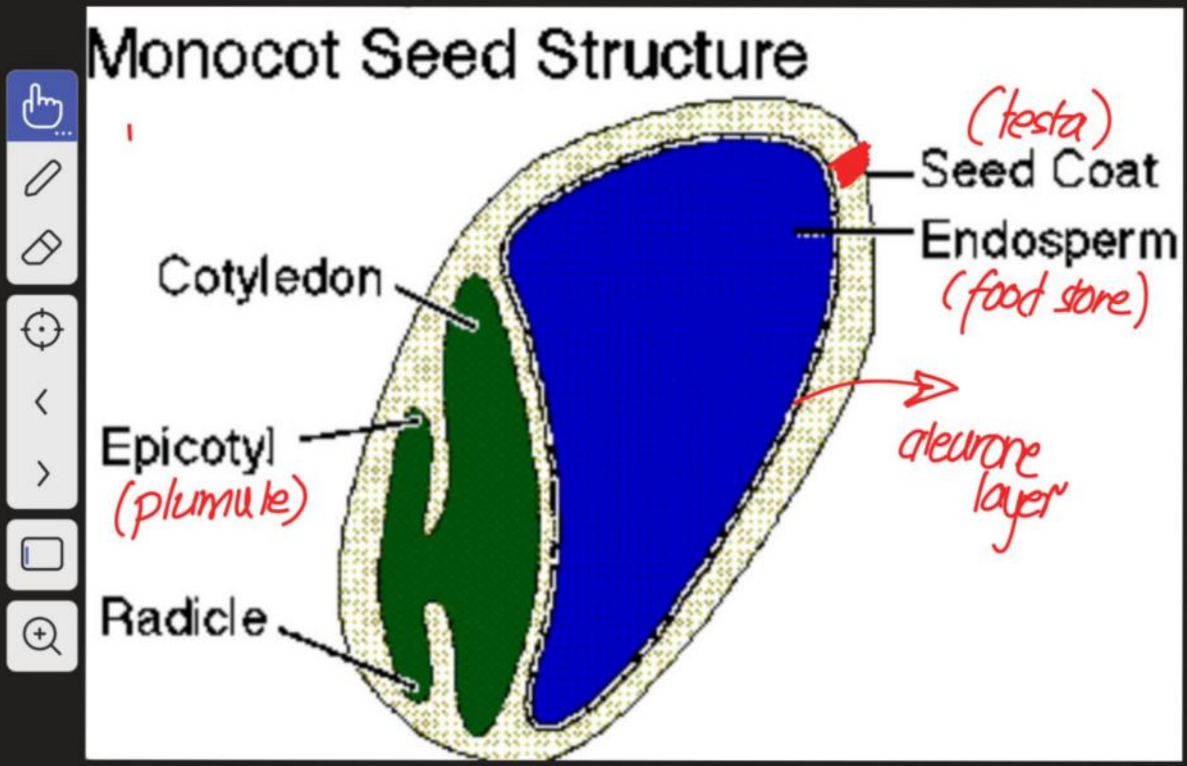
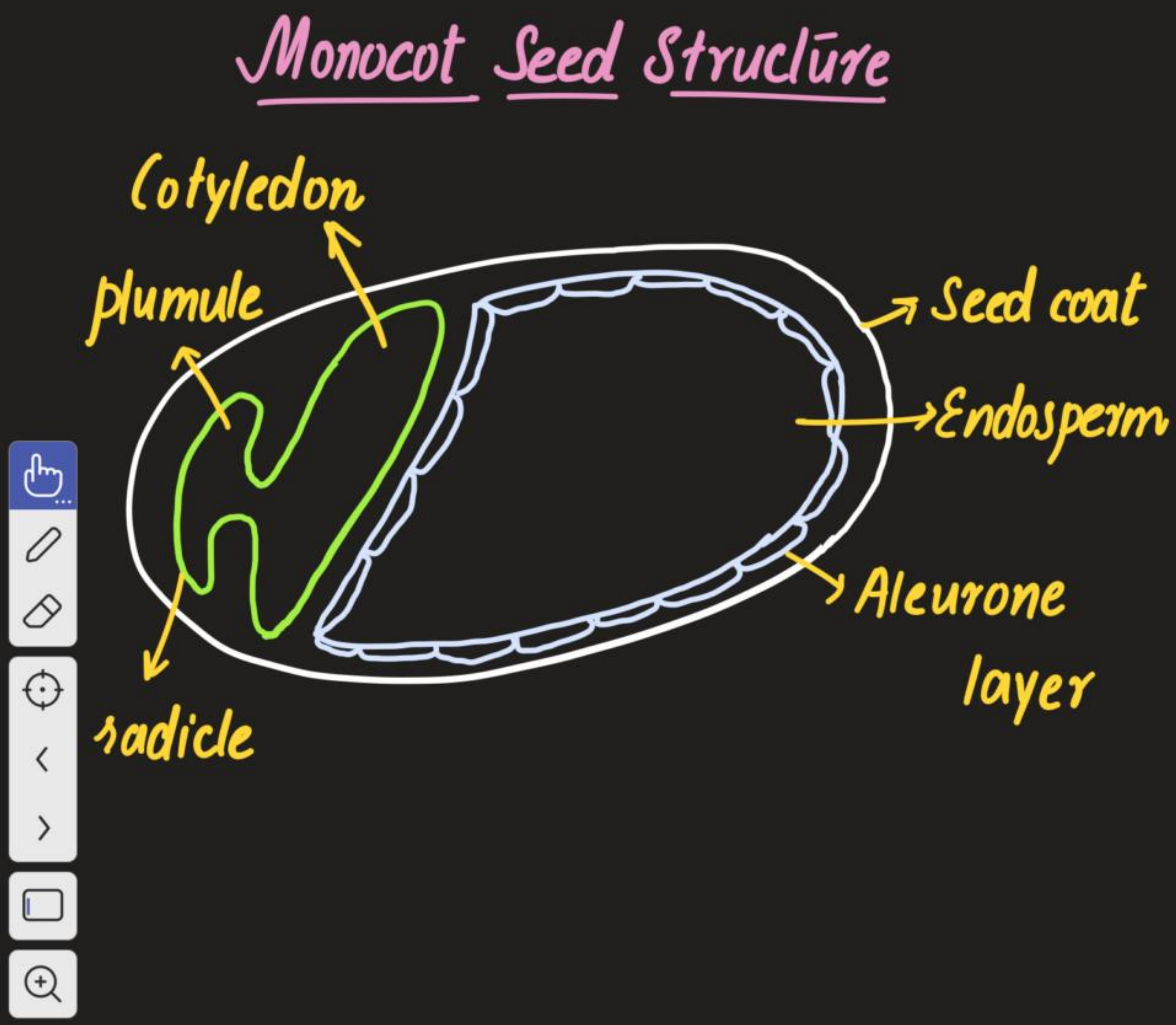
Monocot Seed Structure




Monocot Seed Structure
Cotyledon
plumule
radicle
Seed coat
Endosperm
Aleurone layer

Gibberellins and seed germination

* A monocotyledonous seed consists of three major components:
  1. Testa
  2. Endosperm
  3. Embryo
* Seed coat (Testa) → waxy layer that prevents the embryo from mechanical injury and desiccation.
* Endosperm → food reserve for the embryo
  Contains starch and/or lipids which can

be hydrolysed to produce sugars necessary for the growth of the embryo.

* Aleurone layer → surrounding the endosperm contains cells that store proteins which can be hydrolysed during germination to provide amino acids. It releases amylase and other storage proteins in response to GA.

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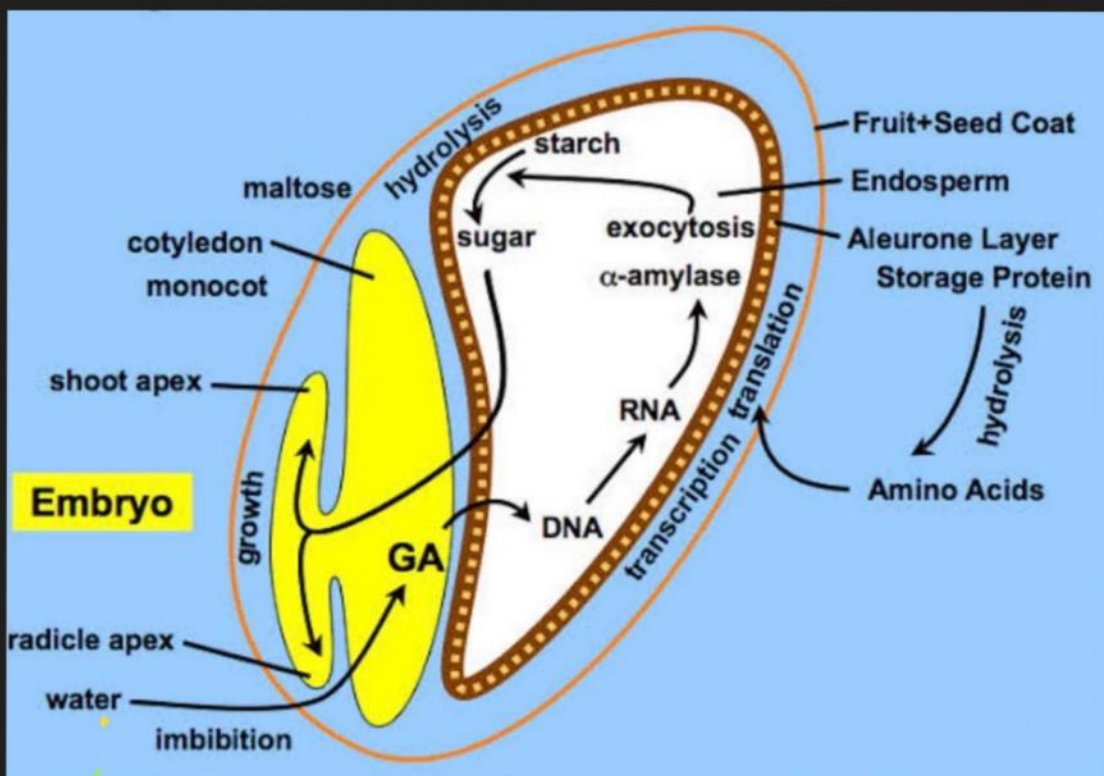
* **Embryo** → consists of one cotyledon (monocot), a plumule and a radicle.

1. Cotyledon is the site of production of GA.
2. Plumule is the developing shoot.
3. Radicle is the developing root.

Barley Seed Germination
(growth of the embryo)



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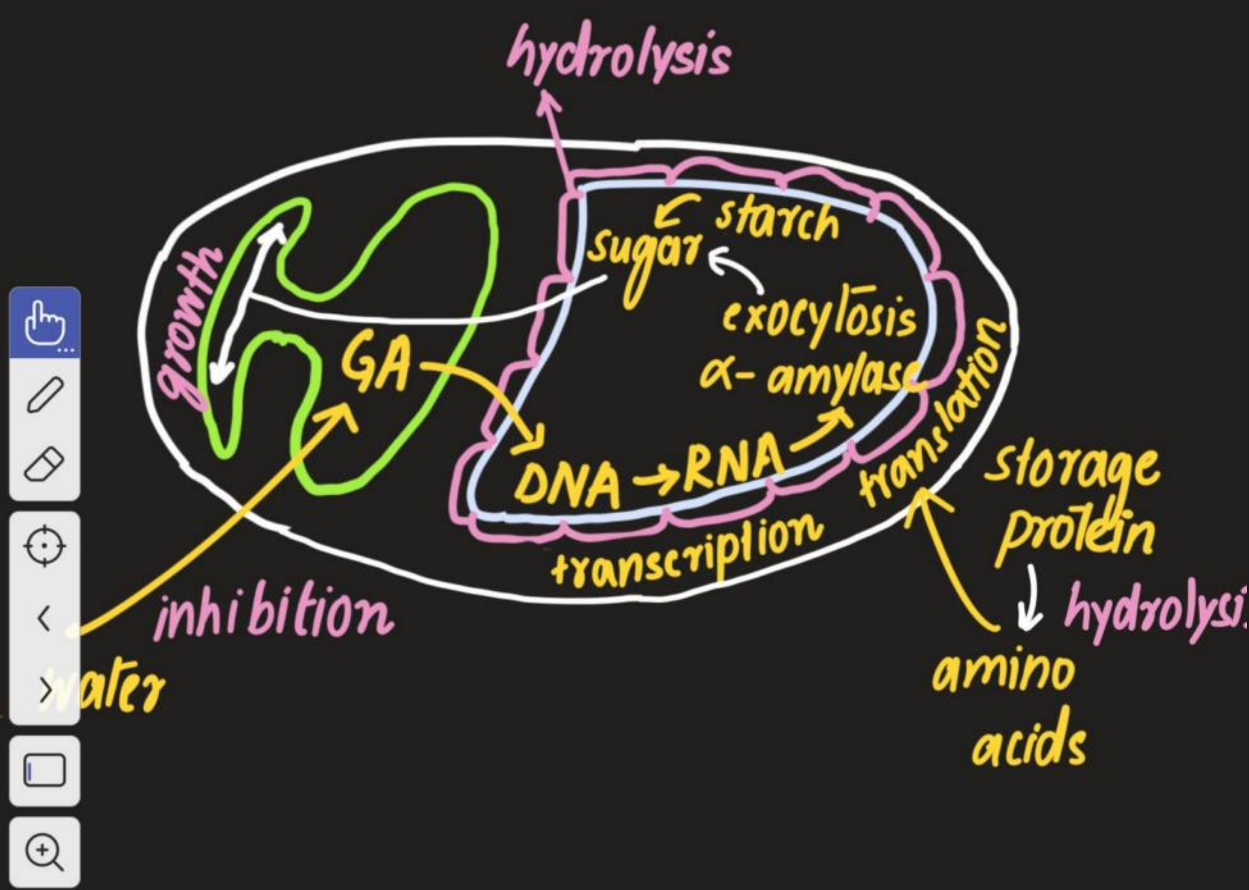
Barley Seed Germination



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Q: Describe and explain how gibberellins are involved in the germination of wheat or barley seeds?

Ans: Germination refers to the growth of embryo within the seed. Seed absorbs water by osmosis (imbibition) which leads to activation of gibberellic acids within the cotyledons (GA). The GA diffuse to the aleurone layer where it switches on transcription of the amylase gene by causing destruction of DELLA proteins.

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The amylase gene codes for the enzyme amylase. Amylase is released via exocytosis into the endosperm where it catalyses the hydrolysis of starch into maltose. Maltose is further broken down to form glucose. Glucose moves via diffusion to the growing plumule and the radicle where it serves as a substrate for,

a) aerobic respiration to release energy in the form of ATP.

b) the formation of cellulose which is required to build the plant cell wall.

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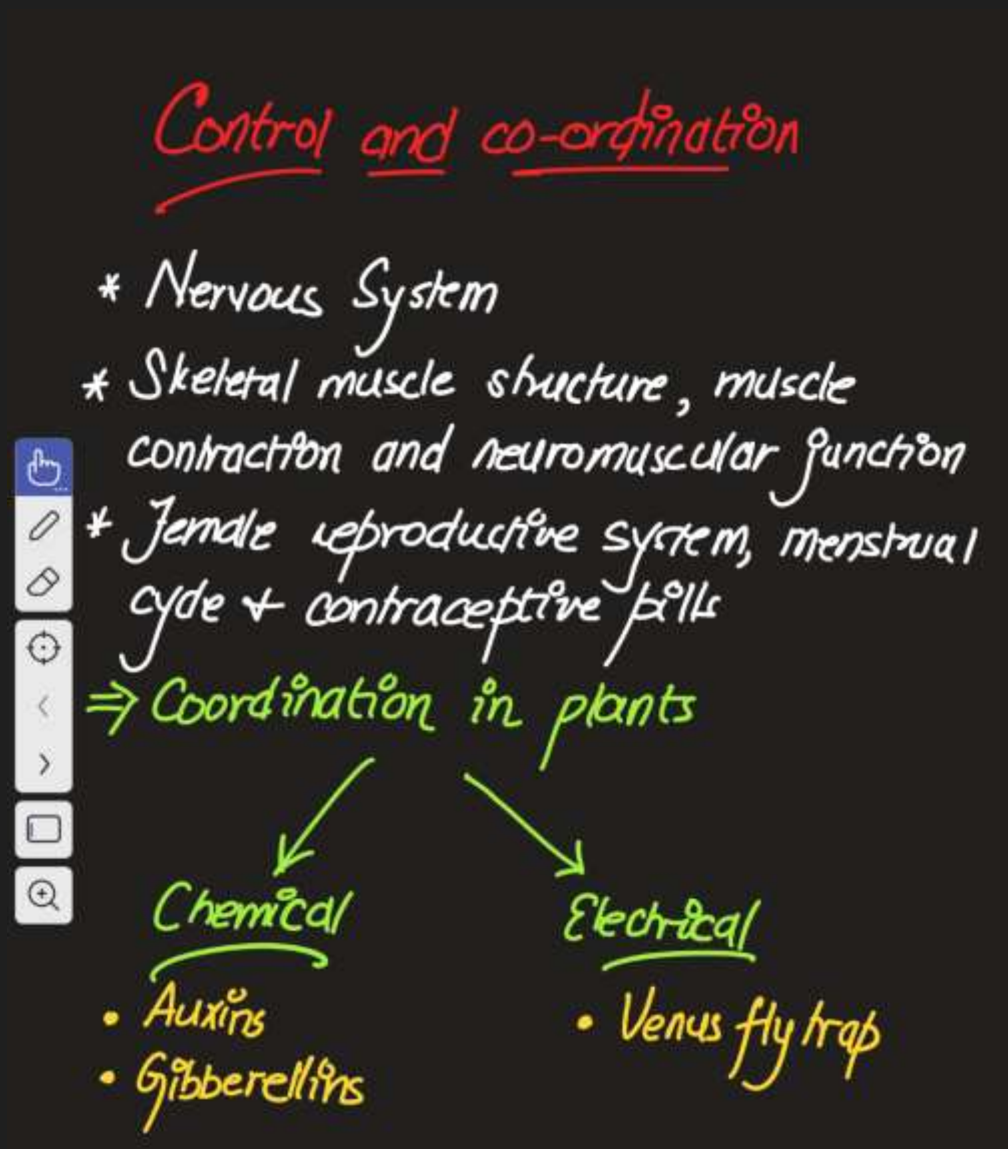
Control & Coordination



With

Mohammad Hussham Arshad, MD

ADVANCED LEVEL BIOLOGY 9700

UNIT 15: Control & Coordination

Learning Objectives:

- Gibberellins & stem elongation
- Venus fly trap

Video Lecture 16 Slides

Mohammad Hussham Arshad, MD
Biology Department

Control and co-ordination

* Nervous System
* Skeletal muscle structure, muscle contraction and neuromuscular function
* Female reproductive system, menstrual cycle + contraceptive pills

⇒ Coordination in plants

Chemical
- Auxins
- Gibberellins

Electrical
- Venus fly trap

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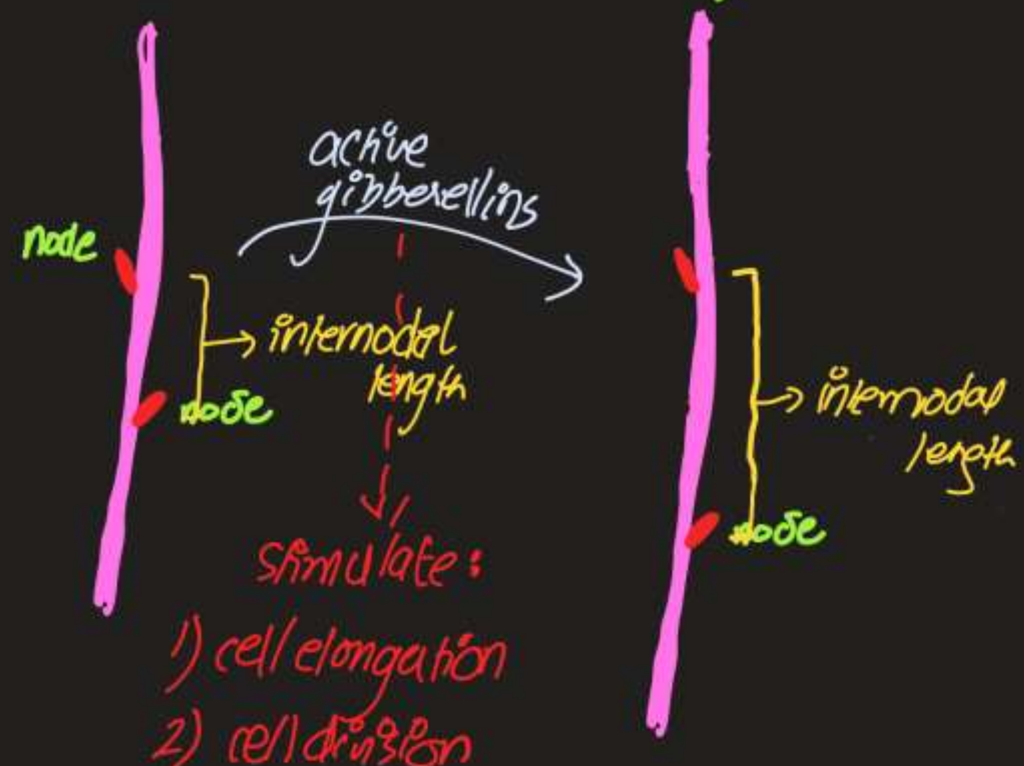
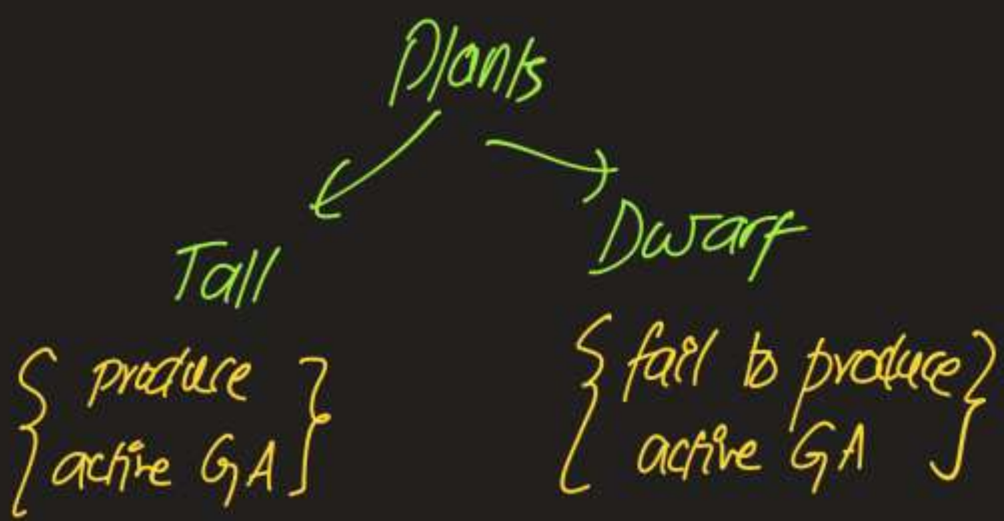
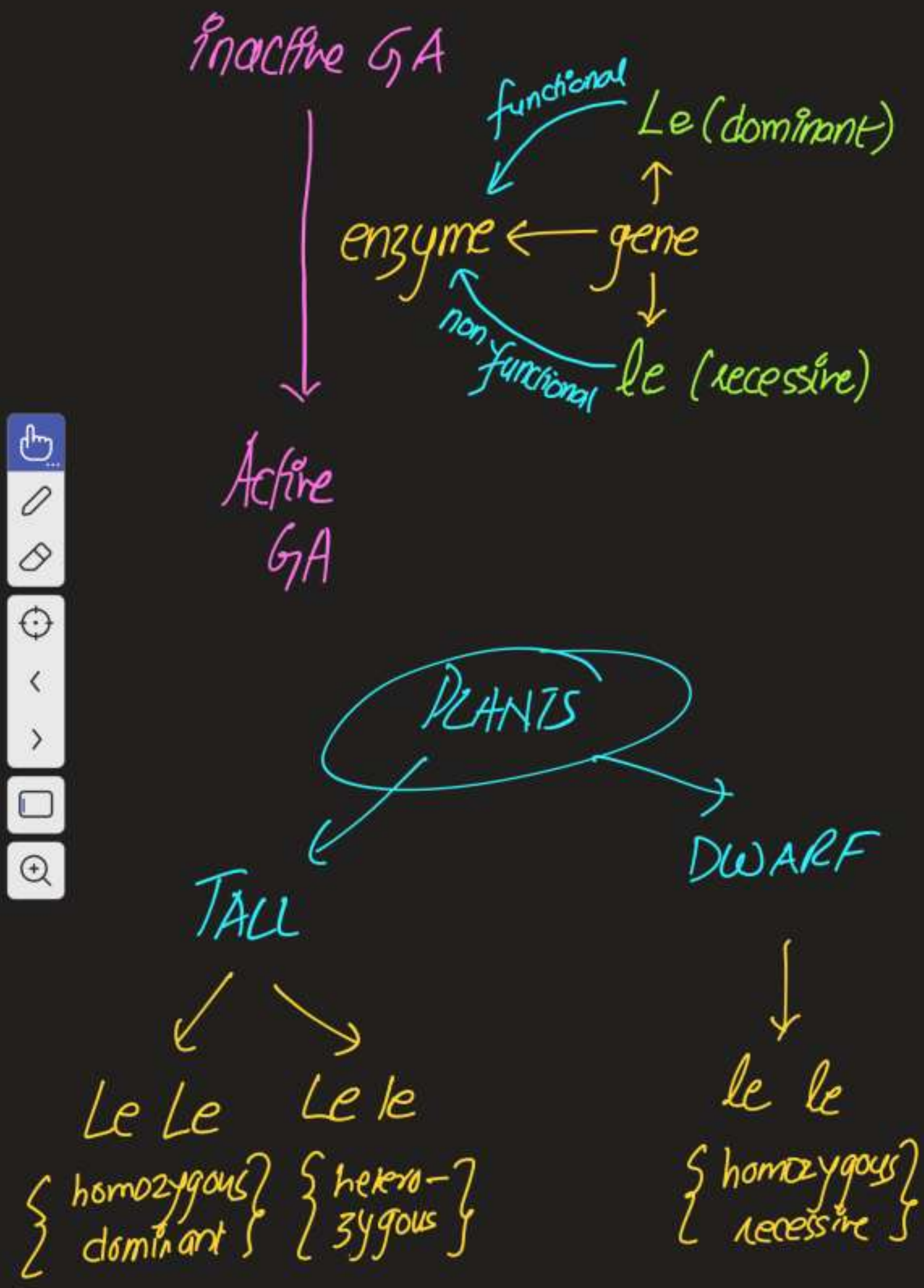
Gibberellins and stem elongation






inactive GA
functional
Le (dominant)
enzyme
gene
non-functional
le (recessive)
Active GA
PLANTS
TALL
DWARF
Le Le
Le le
le le
homozygous dominant
hetero-zygous
homozygous recessive

Gibberellins and stem elongation:

* Gibberellins are known to induce stem elongation by;

1. Causing cell division and elongation.
2. which leads to an increase in the internodal length (length b/w consecutive nodes). A node is the area on the stem where the bud is located.
3. GA works with auxins by activating expansins that loosen cell walls, thereby altering the elasticity of cell walls.

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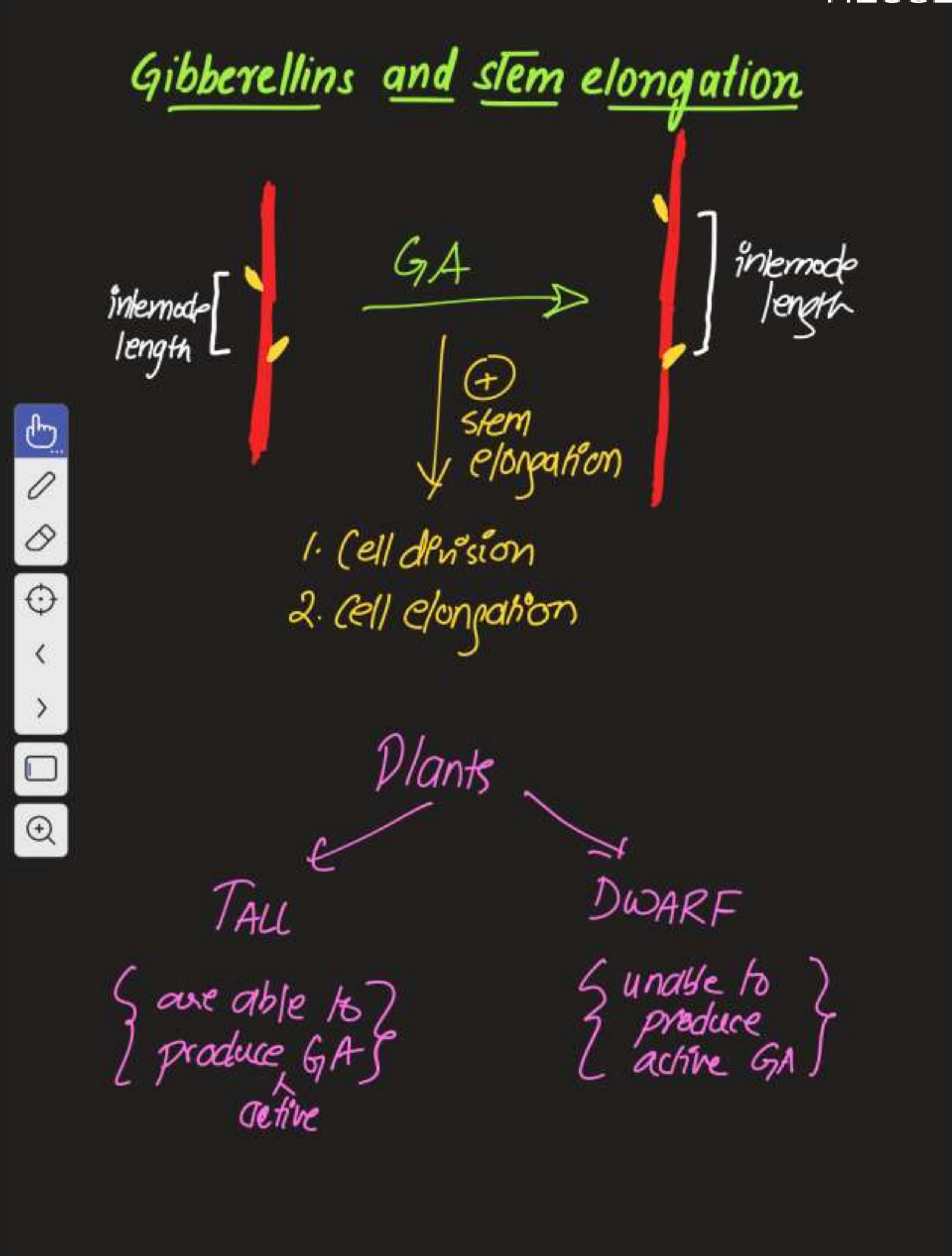
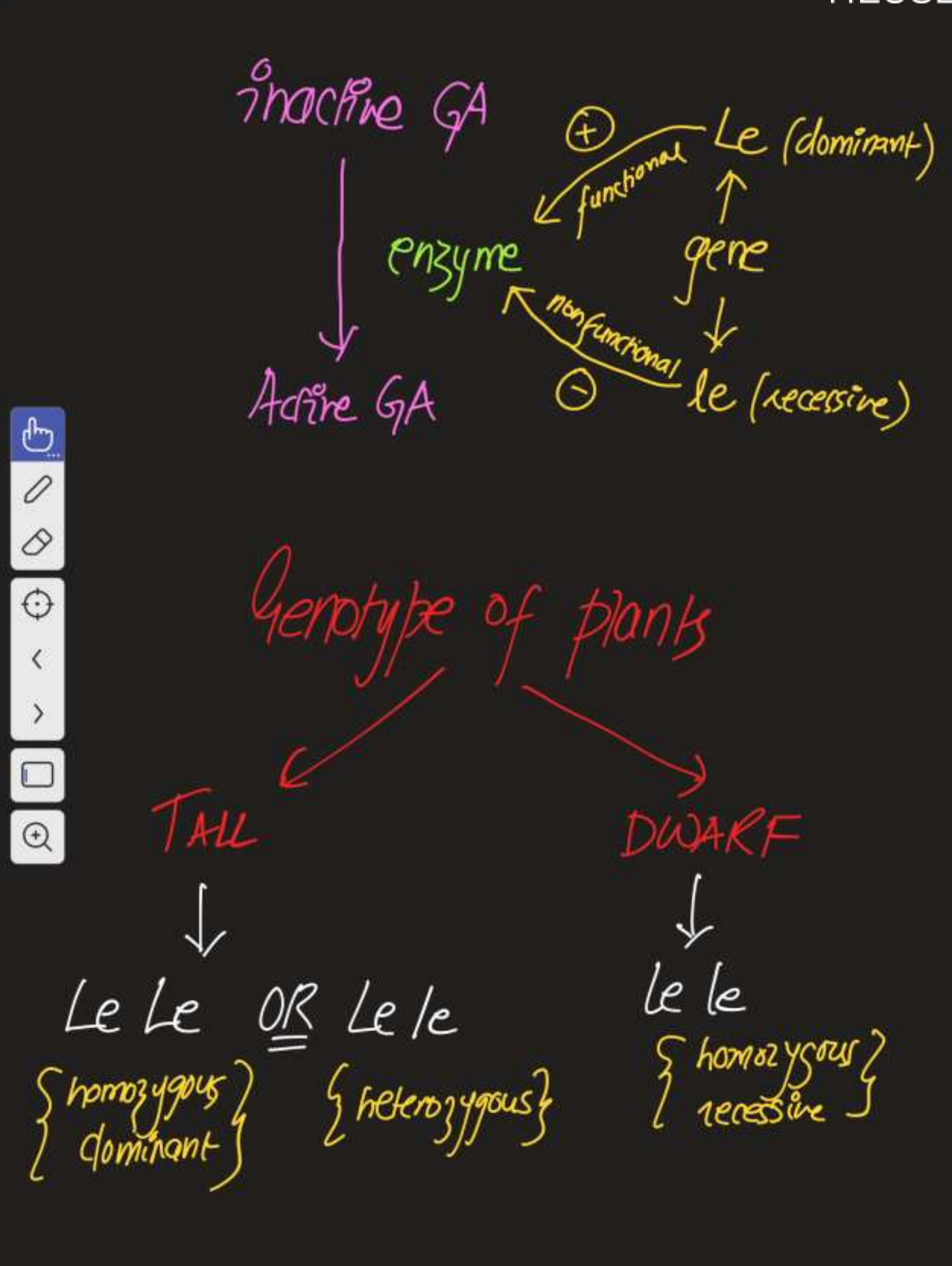

Gibberellins and stem elongation
GA
internode length
internode length
+ stem elongation
1. Cell division
2. Cell elongation
Plants
TALL
DWARF
{ are able to produce GA }
active
{ unable to produce active GA }


inactive GA
Active GA
enzyme
+
functional
Le (dominant)
gene
nonfunctional
−
le (recessive)
Genotype of plants
TALL
DWARF
Le Le OR Le le
{homozygous dominant}
{heterozygous}
le le
{homozygous recessive}

Gibberellins and stem elongation:

* Gibberellins are known to induce stem elongation by;

1. Causing cell division and elongation which leads to an increase in the internodal length (length b/w consecutive nodes). A node is the area on the stem where the bud is located.

2. GA switches on the transcription of genes involved in stem elongation.

3. GA works with auxins by activating expansins that loosen cell walls, thereby altering the elasticity of cell walls.

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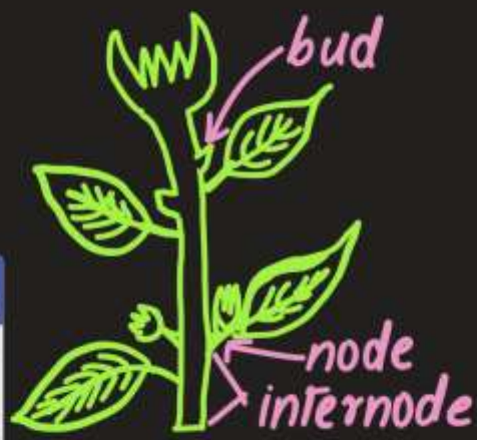
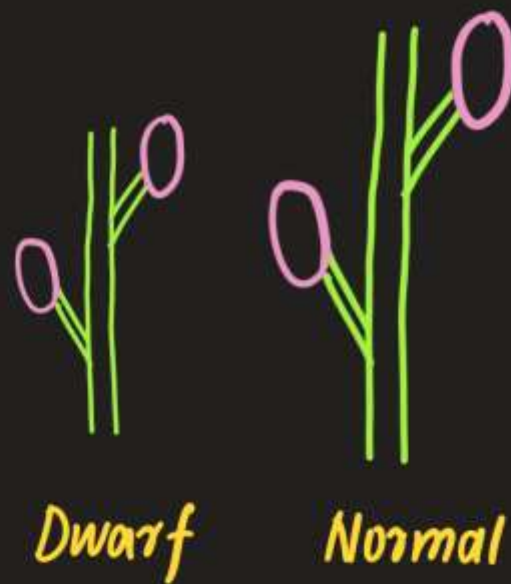
4. When dwarf plant varieties are given active gibberellins, they respond by growing taller. This is probably because they contain inactive forms of gibberellin due to the presence of recessive alleles (le). Dominant allele (Le) leads to production of active gibberellins by producing an enzyme required for the production of active gibberellic acid (GA_1).

5. GA also blocks the actions of certain inhibitors of stem growth that may

naturally be present within the plant stem.





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Q : Describe the role of gibberellins in stem elongation?

Ans: Gibberellins is a family of plant growth regulators which stimulate cell elongation and division, thereby increasing the internodal length. The gene that determines length of stem in plants has two alleles: a dominant allele (Le) & a recessive allele (le). The dominant allele codes for a functional copy of the enzyme needed to activate inactive

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gibberellins. The recessive allele codes for a non-functional copy of the same enzyme. Therefore tall plants are either homozygous dominant (Le Le) or heterozygous (Le le). Dwarf plants are homozygous recessive (le le) and therefore fail to produce active gibberellins.

Q: Explain the control of gibberellin synthesis and outline how gibberellin stimulates cell elongation?

Venus fly trap

Venus fly trap

1. Venus fly trap is a carnivorous plant.
2. It survives in water logged anaerobic soil which is poor in nitrogen rich ions.
3. The venus fly trap therefore obtains extra nitrogen from digestion of insects.

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Structure:

① The leaves of the venus fly trap are modified to form 2 lobes that are attached at the hinge region.

② The cells within the hinge region are termed as hinge cells.

③ The inner surface of the lobes is red in colour.

④ Each lobe contains 3 mechanoreceptors (stiff sensory hair) which transduce mechanical stimuli into an electrical signal.

(5) The periphery of the inner surface contains nectar glands which secrete nectar.

(6) The entire inner surface is rich in digestive glands which secrete proteases to digest the insect meal.

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(7) The insects are attracted to the Venus fly trap due to the following features;

a) the red colour of the lobes

b) the scent

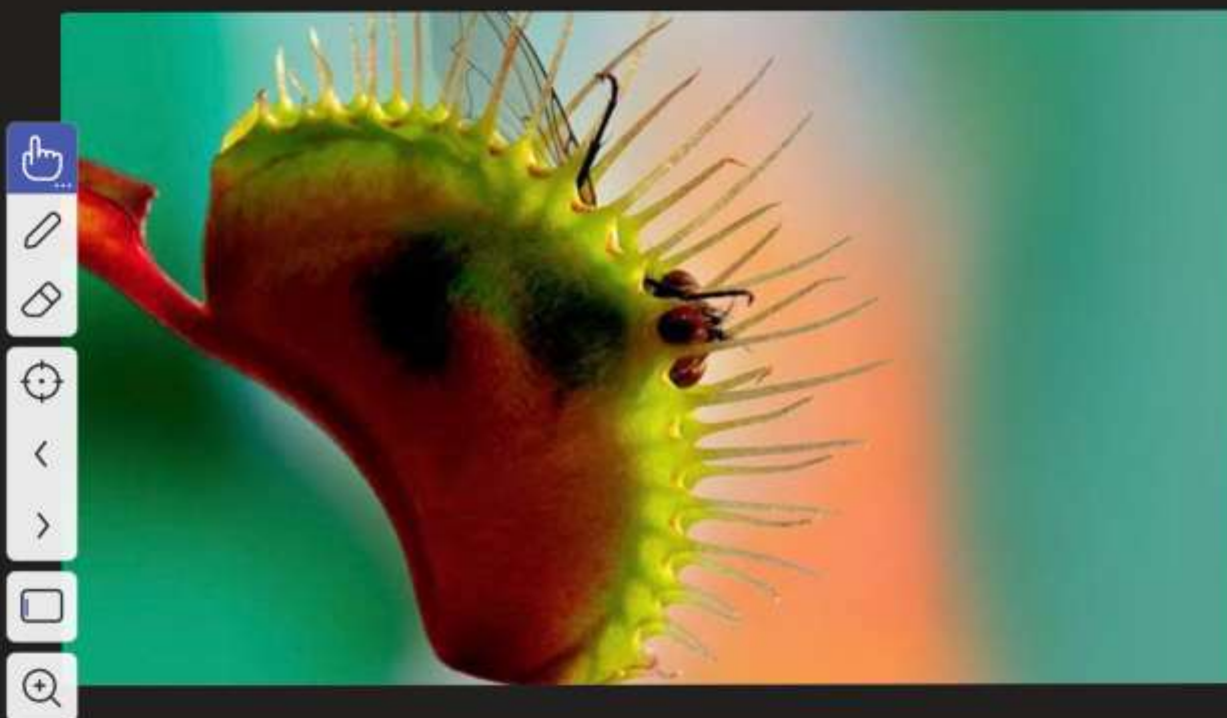
c) nectar produced by the nectaries

d) temperature of the lobes

(8) When the trap is open the inner surface of the lobes is convex and the outer surface is concave.

(9) The ends of the lobes have stiff hairs which serve as prison bars when the trap closes to form an external stomach

Digestion of The Insect Meal



Digestion of The Insect Meal

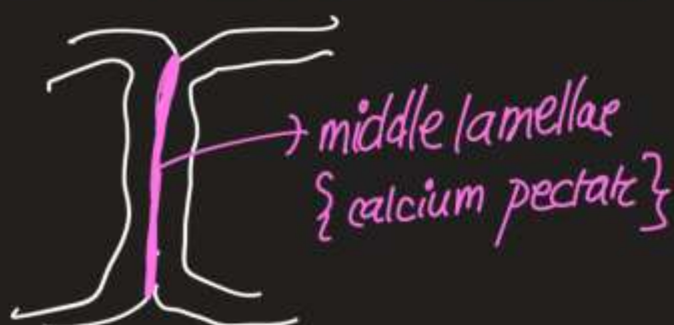
① Persistent stimulation of the sensory hairs causes Ca^{2+} ions influx into the cells of digestive glands.

② The cells release proteases via exocytosis.

③ Proteases break down proteins within the insects to form amino acids.

④ These amino acids are further broken down to release nitrogen rich mineral ions that are absorbed by the lobes.

Mechanism of Trapping



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Mechanism of Trapping

① Deflection of a sensory hair on the inner surface of the lobe leads to opening of Ca^{2+} ion channels in the cells at the base of the hair.

receptor

② Entry of Ca^{2+} ions into these cells generates a receptor potential.

③ A second stimulation of a sensory hair within 35 seconds initiates an action potential. The action potential

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rapidly spreads to the hinge cells in the hinge region.

(4) The change in electrical potential of the hinge cells increases the concentration of auxins.

(5) Auxins bind to the receptors and activate a hydrogen ion ATPase pump which pumps hydrogen ions into the cell wall.

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⑥ Low pH within the cell wall:

a) activates expansins which break non-covalent interactions b/w cellulose microfibrils. This changes the elasticity of the cell wall.

b) dissolves calcium pectate thereby releasing calcium ions into hinge cells.

⑦ Increased conc. of Ca^{2+} ions lowers the water potential within the hinge cells which enables water to follow via osmosis.

(8) The hinge cells therefore expand, the outer surface of the lobe becomes convex which causes the trap to shut close.

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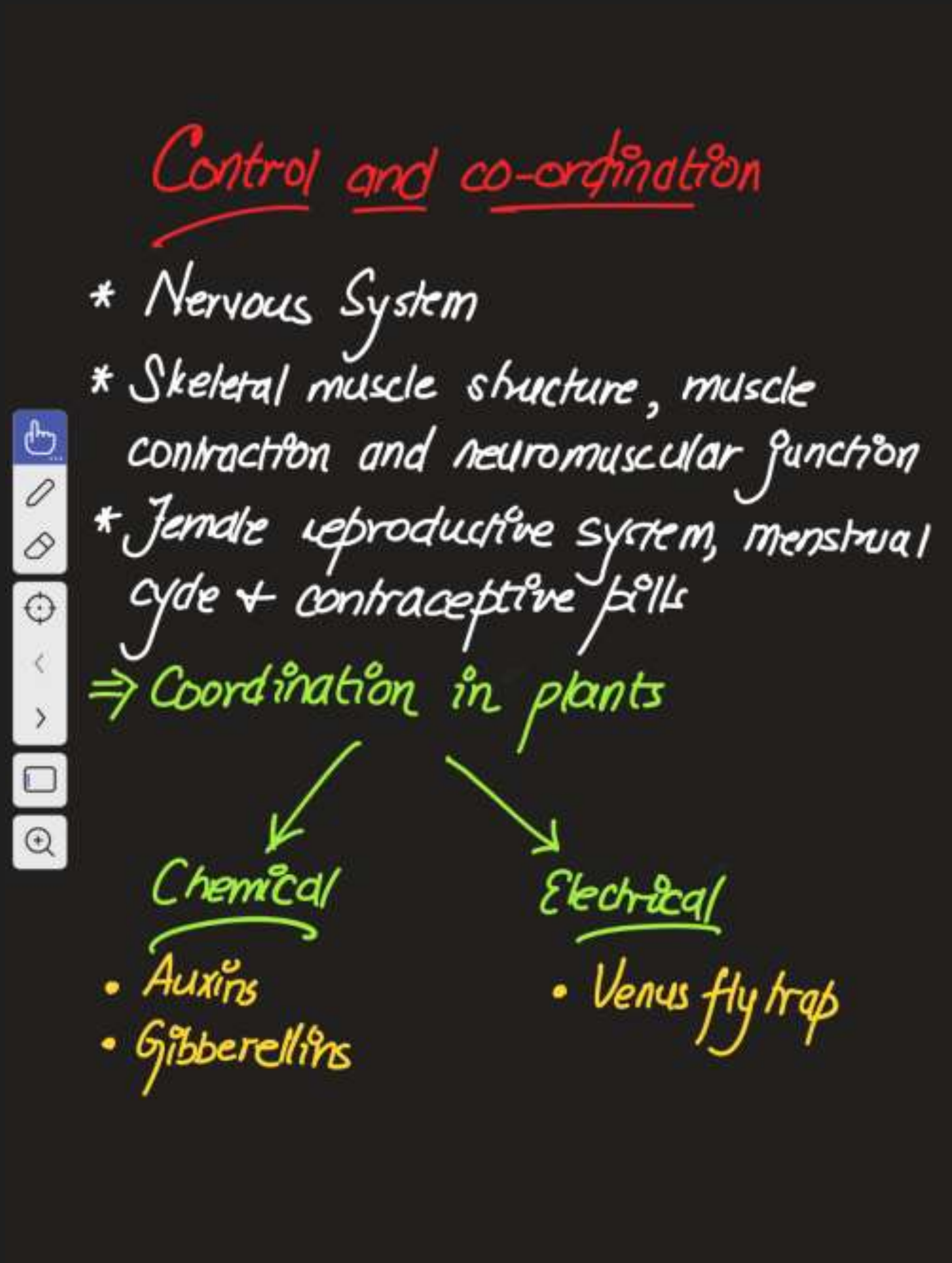
Control & Coordination



With

Mohammad Hussham Arshad, MD

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UNIT 15: Control & Coordination

Learning Objectives:

- Practice questions

Video Lecture 17 Slides

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Questions

Q1.

6 (a) Thyrotoxic myopathy (TM) is a neuromuscular disorder caused by overproduction of the thyroid hormone thyroxine. One of the main symptoms of TM is muscle fatigue.

Fig. 6.1 outlines the effects of overproduction of thyroxine on striated muscle.

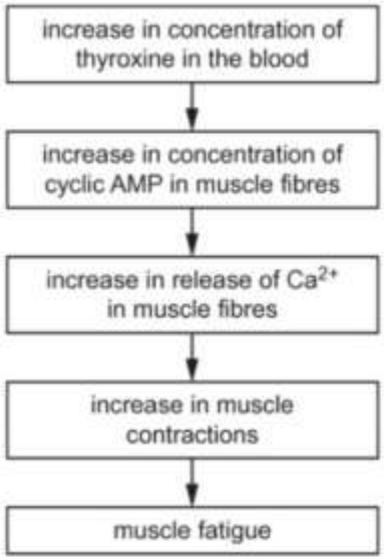

Fig. 6.1

(i) The concentration of thyroxine in the blood usually fluctuates around a set point.

Name the mechanism that keeps the concentration of thyroxine in the blood close to its set point.

negative feedback effect .... [1]

(ii) Name the part of the striated muscle fibre that releases Ca^{2+}.

sarcoplasmic reticulum .... [1]

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(iii) Describe the role of Ca^{2+}, troponin and tropomyosin in the contraction of striated muscle.

* Ca^{2+} bind to troponins
* troponin molecules change shape
* tropomyosin moves and exposes
* myosin binding site on the actin
* myosin head attaches to the actin to form cross bridge
* head bends/ rotates to pull the thin filament towards the M-line (power stroke)

[4]

(iv) Cyclic AMP (cAMP) is also involved in the response of liver cells to glucagon.

Describe the role of cAMP in the response of liver cells to glucagon.

* acts as a second messenger
* binds to and activates protein kinases

[2]

(b) An increase in the concentration of thyroxine in the blood can lead to a condition called insulin resistance (IR). IR decreases the sensitivity to insulin of target cells, such as muscle and liver cells.

Suggest how decreased sensitivity to insulin affects target cells.

* decreased uptake of glucose
* decreased glycogenesis
* decreased glycolysis

[3]

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Q2.

7 The Venus fly trap, *Dionaea muscipula*, is a carnivorous plant, native to wetlands of the East Coast of the USA. Mineral ions from decayed organisms are often washed away in these wetlands.

Fig. 7.1 shows a Venus fly trap leaf.

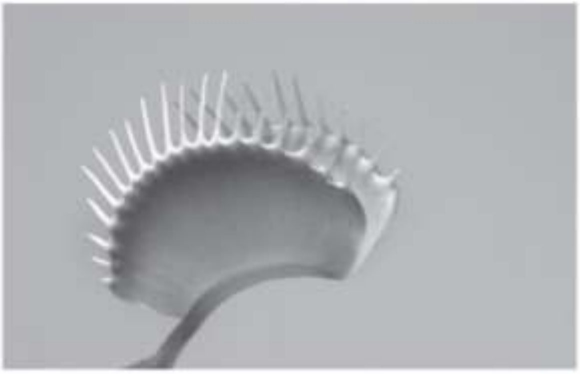

Fig. 7.1

(a) Suggest why a Venus fly trap benefits from catching insects in these wetlands.

* digest the insects to release mineral ions (NO_3^-) which are absorbed by the lobes
* since the soil is deficient in these mineral ions. [2]

(b) (i) The leaves of the Venus fly trap will close if stimulated by an insect.

State which part of the leaf detects the stimulus.

sensory hairs [1]

(ii) Explain how the plant does not waste energy by closing when it does not need to, such as when a large drop of rain touches the receptor.

requires two stimulations within 35 seconds [1]

(c) Fig. 7.2 is a graph of an action potential in a human neurone.

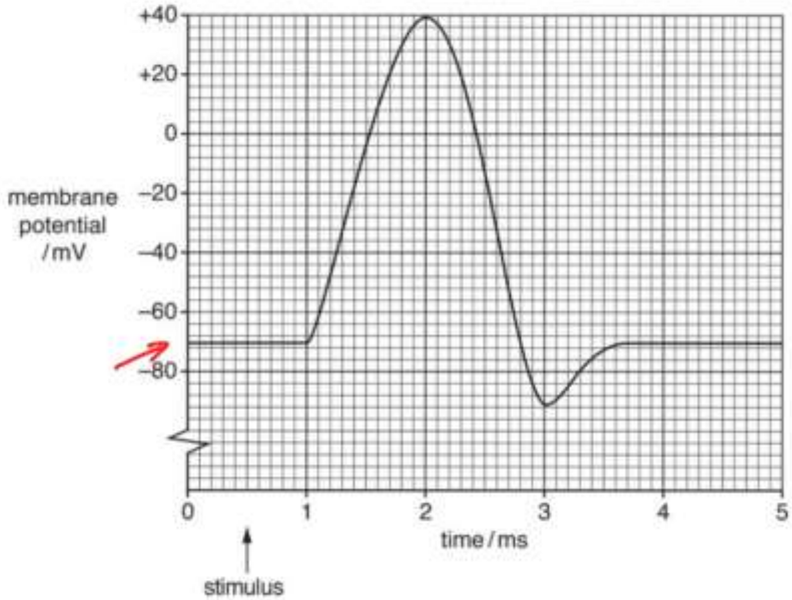

Fig. 7.2

Fig. 7.3 is a graph of an action potential in leaf cells of a Venus fly trap.

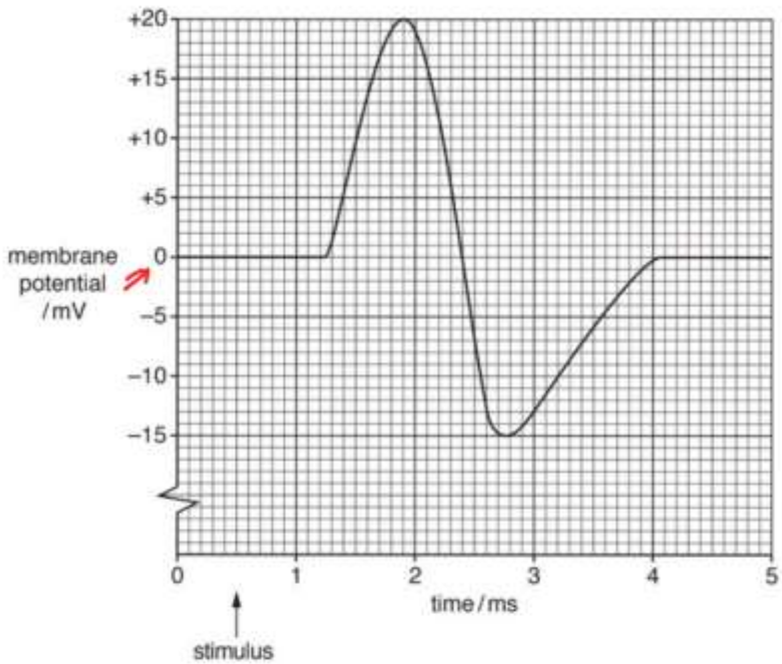

Fig. 7.3

With reference to Fig. 7.2 and Fig. 7.3, describe how the action potential of the Venus fly trap differs from that of a human.

Venus fly trap,
* smaller depolarisation
* shorter duration of depolarisation
* longer duration of action potential
* RMP = 0 mV

[3]

(d) Describe how the production of action potentials in the leaf cells of the Venus fly trap can result in the leaves closing and trapping an insect.

* depolarisation of the hinge cells
* increases the intracellular auxin conc.
* which activates the H^+ pump on the CSM
* H^+ are pumped into the cell wall activating expansin which loosen the
* bonds between cellulose microfibrils AND
* low pH also dissolves Ca pectate in the middle lamella enabling Ca^{2+} to enter the hinge cells
* water follows via osmosis → hinge cells expand
* closing the trap

[5]

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Q3.

7 (a) Gibberellin is involved in the germination of barley seeds.

In an investigation, aleurone layers from barley seeds were extracted. One sample was treated with gibberellin and the other sample was given no gibberellin treatment. The rate of production of amylase enzyme by the aleurone layers was measured over 15 hours.

The results are shown in Fig. 7.1.

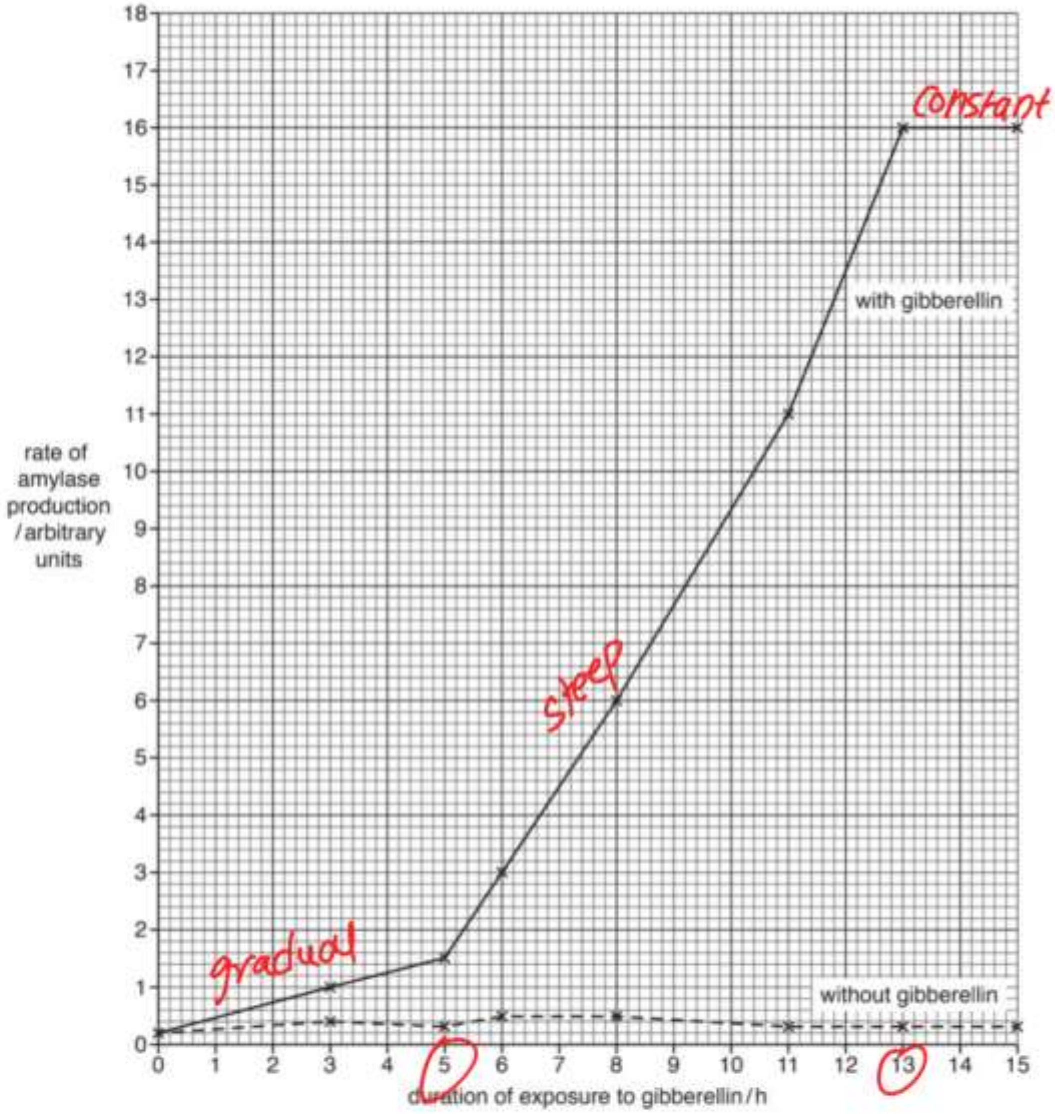

Fig. 7.1

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Describe the results shown in Fig. 7.1.

* greater increase in the rate of amylase production in barley seeds treated with GA
* Gradual rise in the rate of GA treated seeds b/w 0–5 hrs
* steep rise b/w 5–13 hrs and
* constant b/w 13–15 hrs
* for sample NOT treated with GA → rate is constant

[3]

(b) Explain why the aleurone layers of barley seeds need to produce amylase during germination.

* amylase is released into endosperm via exocytosis
* amylase hydrolyses starch into maltose
* maltose is broken down to glucose
* glucose serves as the substrate for respiration → leads to growth of the embryo

[3]

(c) The height of some plants is partly controlled by their genes. Height in pea plants is affected by a gene with two alleles. The dominant allele results in the production of active gibberellin, which stimulates stem elongation.

(i) State the symbol that represents the dominant allele.

Le [1]

(ii) Explain how this dominant allele results in the production of active gibberellin.

* codes for an enzyme that
* converts inactive GA to active GA

[2]

(iii) Active gibberellin stimulates stem elongation by causing the breakdown of DELLA protein repressors so that growth genes can be expressed.

Suggest the effects of the expression of these growth genes.

GA promotes
* cell elongation and
* cell division which leads to
* increase in internodal length

.... [2]

Q4.

1 (a) Fig. 1.1 shows a cholinergic synapse.

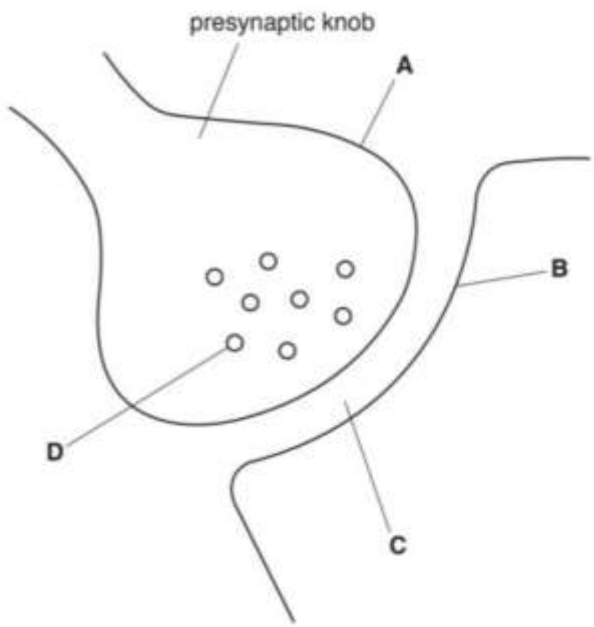

Fig. 1.1

Complete Table 1.1, using the letters **A**, **B**, **C** or **D** from Fig. 1.1, to show the location of compounds and structures associated with a cholinergic synapse.

You may use **A**, **B**, **C** and **D** once, more than once, or not at all.

Table 1.1

compound or structure	location
acetylcholine	D and C
voltage-gated channel	A
receptor protein	B
acetylcholinesterase	C

[4]

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(b) Explain what is meant by a voltage-gated channel.

* transports specific ions
* opens and closes due to voltage change across the membrane

[2]

(c) Explain the role of acetylcholinesterase in a synapse.

* breaks down acetylcholine to choline and acetyl group
* the presynaptic neuron reuptakes choline
* this will prevent persistent depolarisation of the postsynaptic membrane

[3]

(d) Outline the roles of synapses in the nervous system.

* memory and learning
* one-way transmission

[2]

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Q5.

4 (a) Fig. 4.1 shows a transmission electron micrograph of a section through striated muscle.

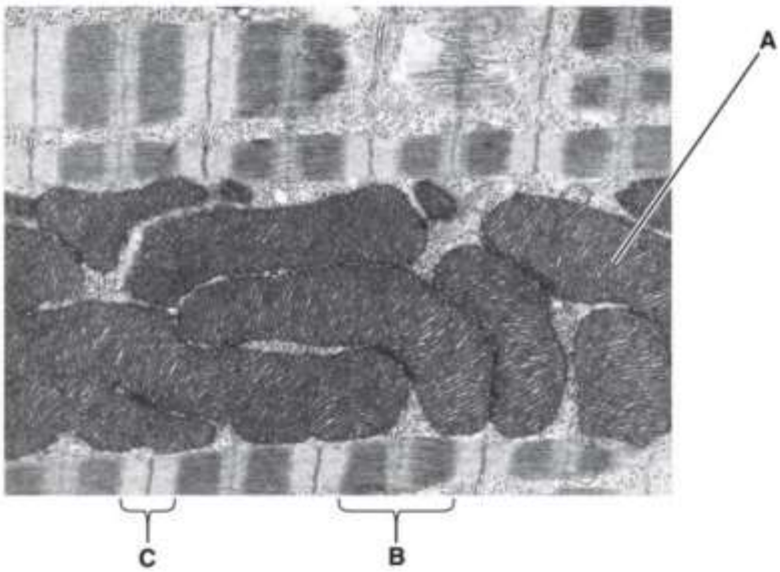

Fig. 4.1

Complete Table 4.1, using the letters **A**, **B** or **C**, to show the location of proteins associated with striated muscle structure.

You may use each letter once, more than once, or not at all.

Table 4.1

protein	location
myosin and actin	B
actin alone	C
ATP synthase	A
ATPase	B

[4]

(b) Explain the role of ATP in the contraction of striated muscle.

....

....

....

....

....

....

....

....

....

.... [5]

Q6.

8 Gibberellin is a plant growth hormone that has a role in germination and in stem elongation.

(a) Outline how gibberellin is involved in activating genes for stem elongation.

.... [2]

(b) Outline the role played by gibberellin in the germination of wheat seeds.

* absorption of water into the seeds
* cotyledons produce GA which diffuse to the aleurone layer
* switches on the transcription of amylase gene
* the enzyme amylase is released into endosperm via exocytosis
* hydrolyses starch → maltose / glucose
* glucose is involved in the growth of the embryo

[4]

(c) The length of stem in pea plants is controlled by a single gene. Pea plants can be either tall or short.

A study was carried out to investigate the effect of applying gibberellin to short pea plants. Two groups of short pea seedlings were used, group **P** and group **Q**.

- Group **P** consisted of 20 seedlings to which a paste containing gibberellin had been applied two days after germination.
- Group **Q** consisted of 20 seedlings to which a paste **without** gibberellin had been applied two days after germination.
- The length of stem of the pea plants was recorded at intervals over 20 days.

The results are shown in Fig. 8.1.

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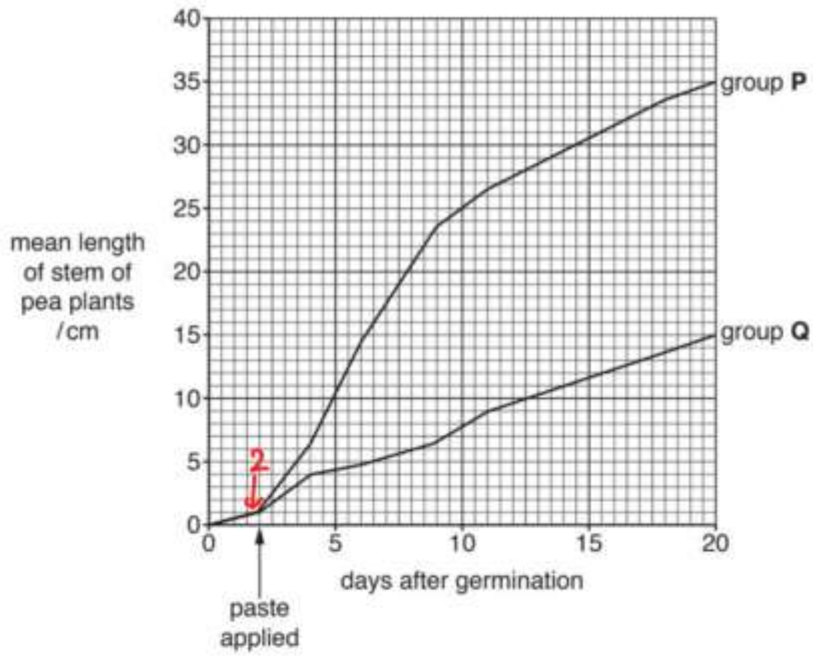

Fig. 8.1

With reference to Fig. 8.1, describe the results of the investigation **and** compare the growth rate of plants in group **P** and group **Q**.

* length of stem the same till day 2
* group P has a greater increase in length over the remaining after applying the pashe
* group P reaches a mean length of 35 cm on day 20
* group Q reaches a mean length of 15 cm on day 20

[4]

(d) Explain the role of the gene controlling stem length in pea plants.

* dominant allele Le of the gene codes for an enzyme
* that converts inactive to active GA
* recessive allele (le) does NOT produce the enzyme that converts inactive to active GA.

[3]