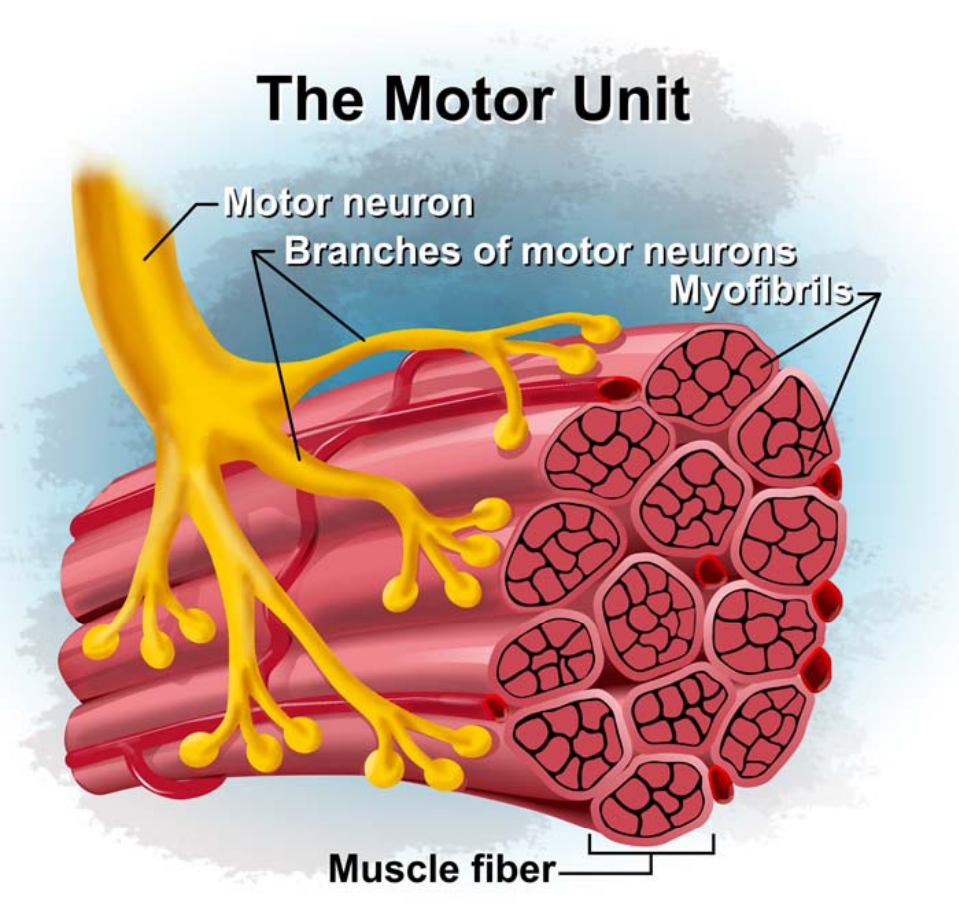
NERVE MUSCLE PHYSIOLOGY

- Dr. Atanu saha

- Study material for B.Sc (H) Physiology 2nd Sem


The Motor Unit
Motor neuron
Branches of motor neurons
Myofibrils
Muscle fiber

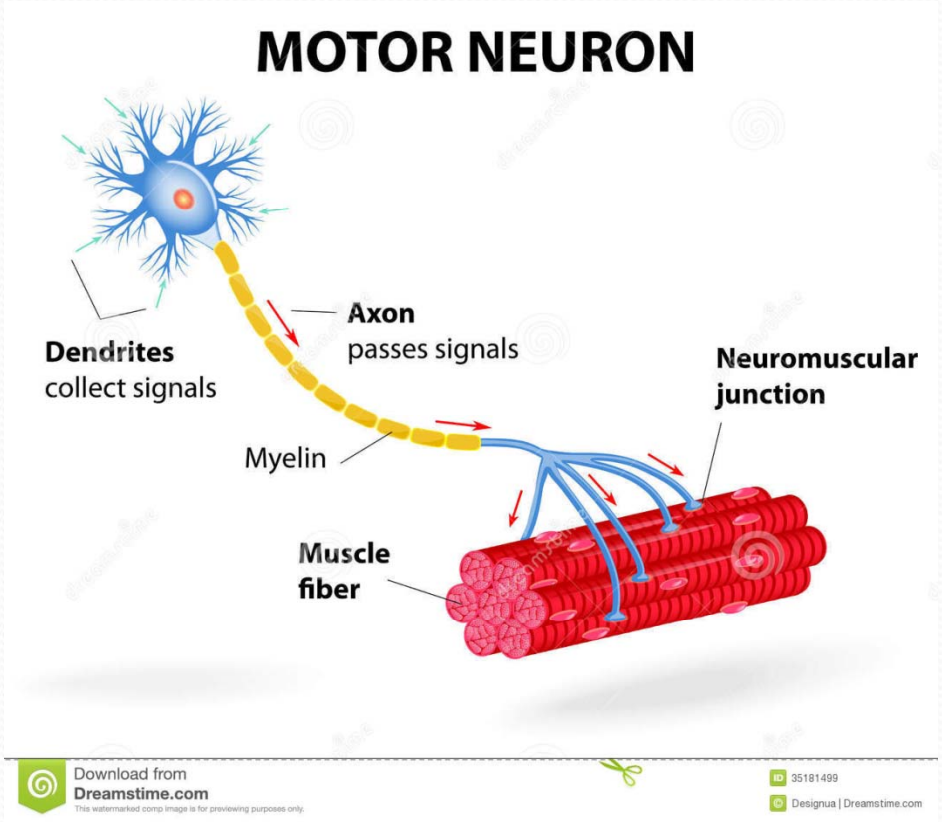
NERVE + MUSCLE+PHYSIOLOGY

Nerve:

The filamentous bands of nervous tissue that connect parts of the nervous system with the other organs, conduct nerve impulses, and are made up of axons and dendrites together with protective and supportive structures.

NERVE + MUSCLE+PHYSIOLOGY

Neuron:



MUSCLE

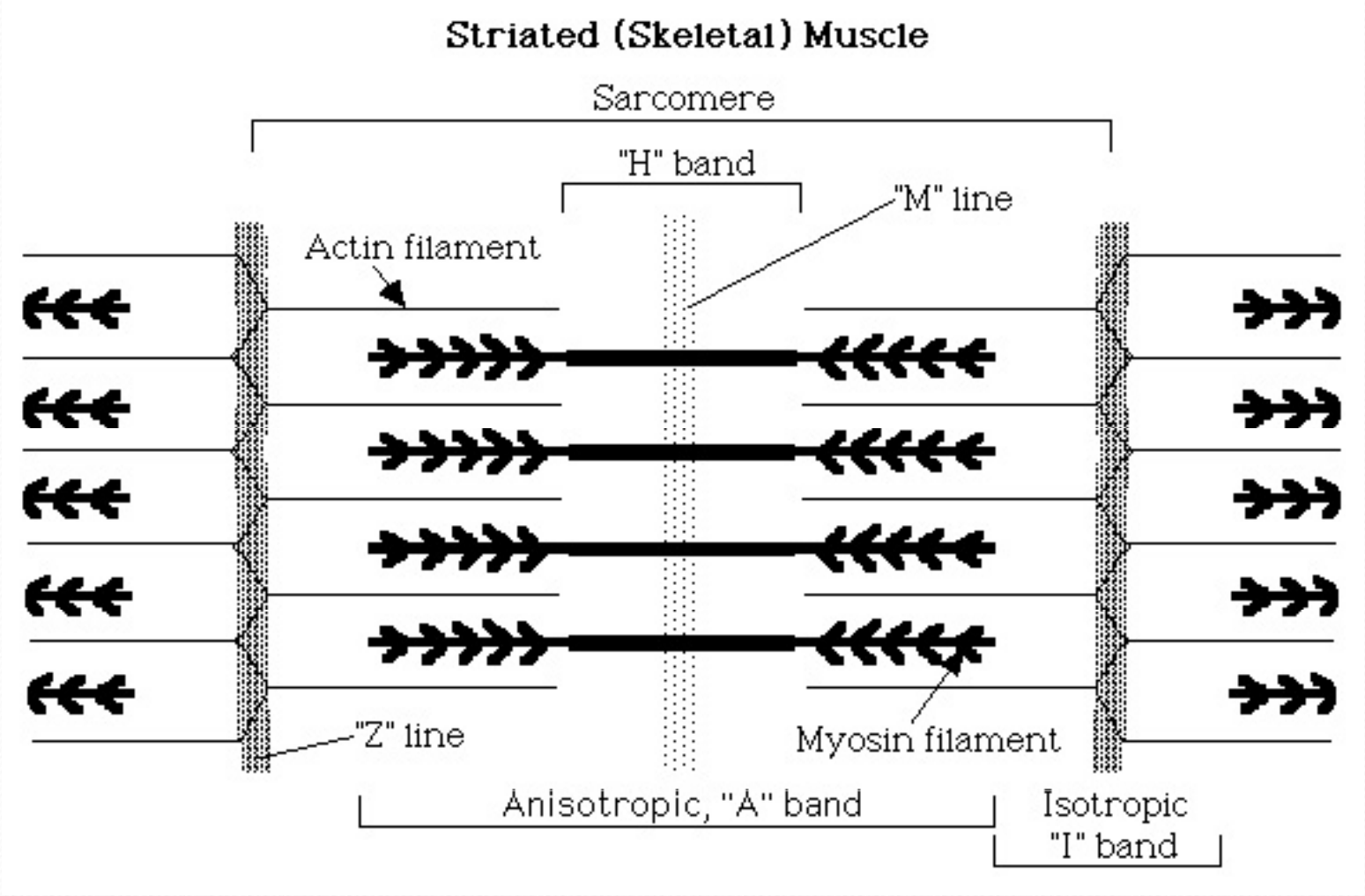
- **Muscle** is a soft tissue
- Muscle cells contain protein filaments of actin and myosin
- Types of Muscle

  a. Skeletal Muscle;

  b. Smooth Muscle; and

  c. Cardiac Muscle.

SKELETAL MUSCLE STRUCTURE



STIMULATION AND CONTRACTION OF SKELETAL MUSCLE

- Excitability- ability to receive and respond to stimulus;
- Contractility- ability to shorten when adequate stimulus is received;
- Extensibility- ability of muscle to be stretched; and
- Elasticity- ability to recoil and resume resting length after stretching.

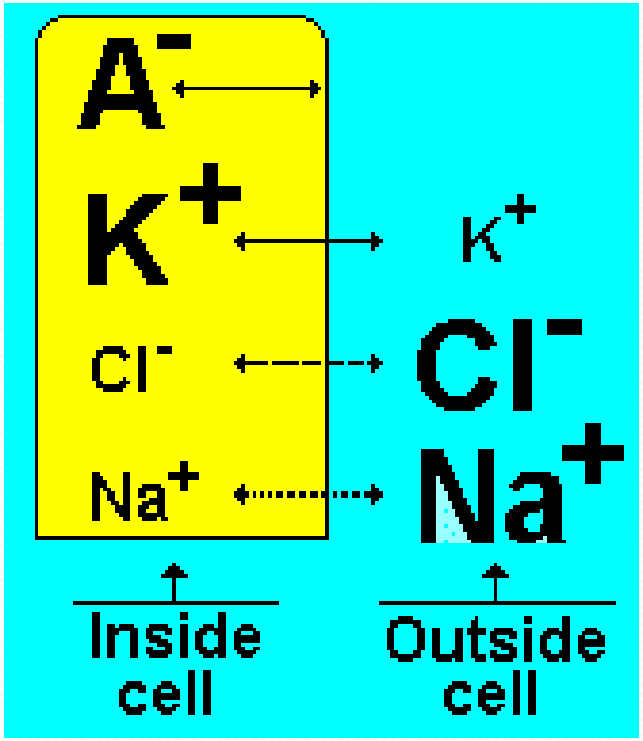
NERVE STIMULUS AND ACTION POTENTIAL

The Nerve Stimulus and Action Potential

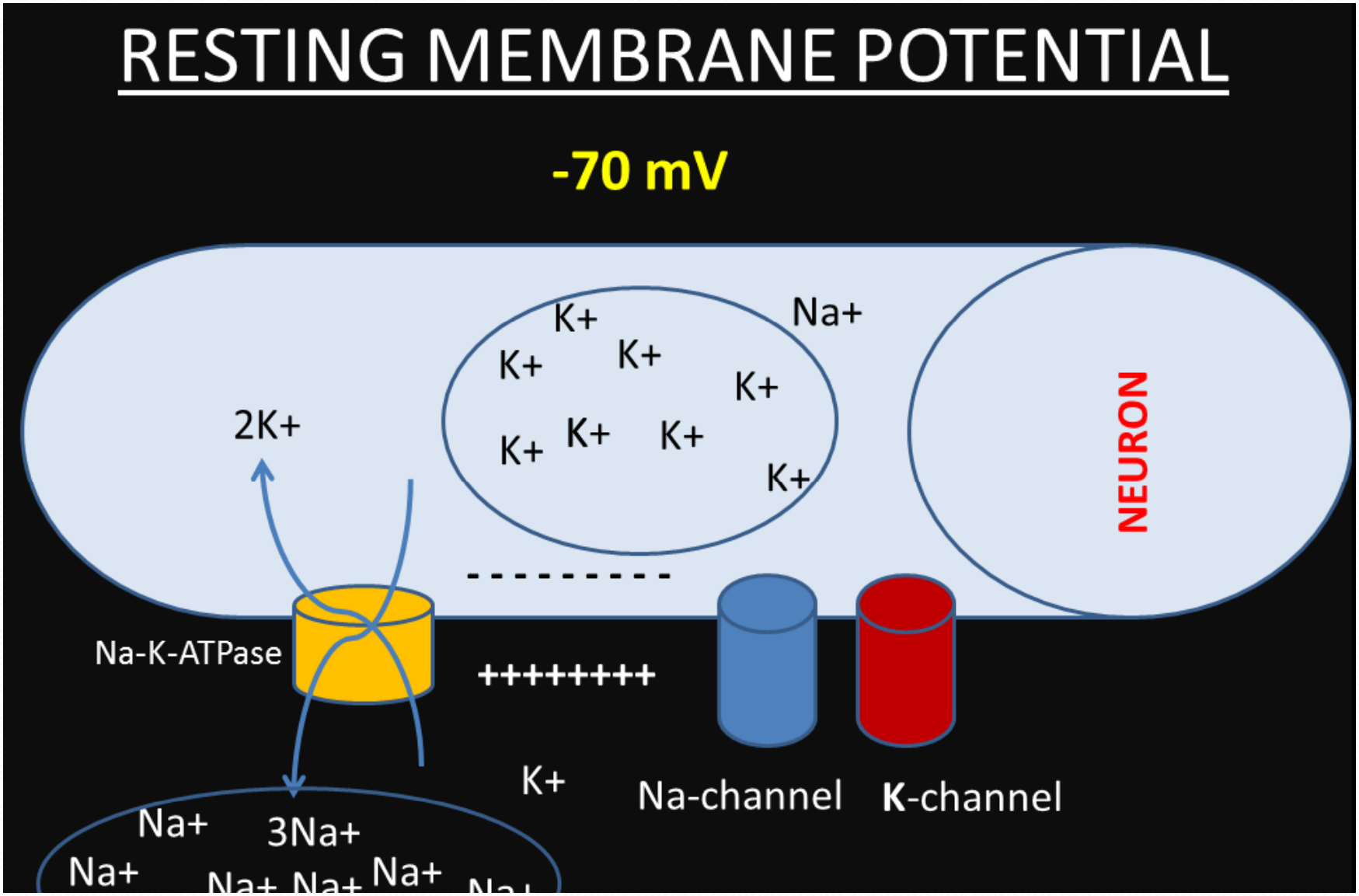
- Skeletal muscles must be stimulated by a motor neuron (nerve cell) to contract
- Motor unit—one motor neuron and all the skeletal muscle cells stimulated by that neuron

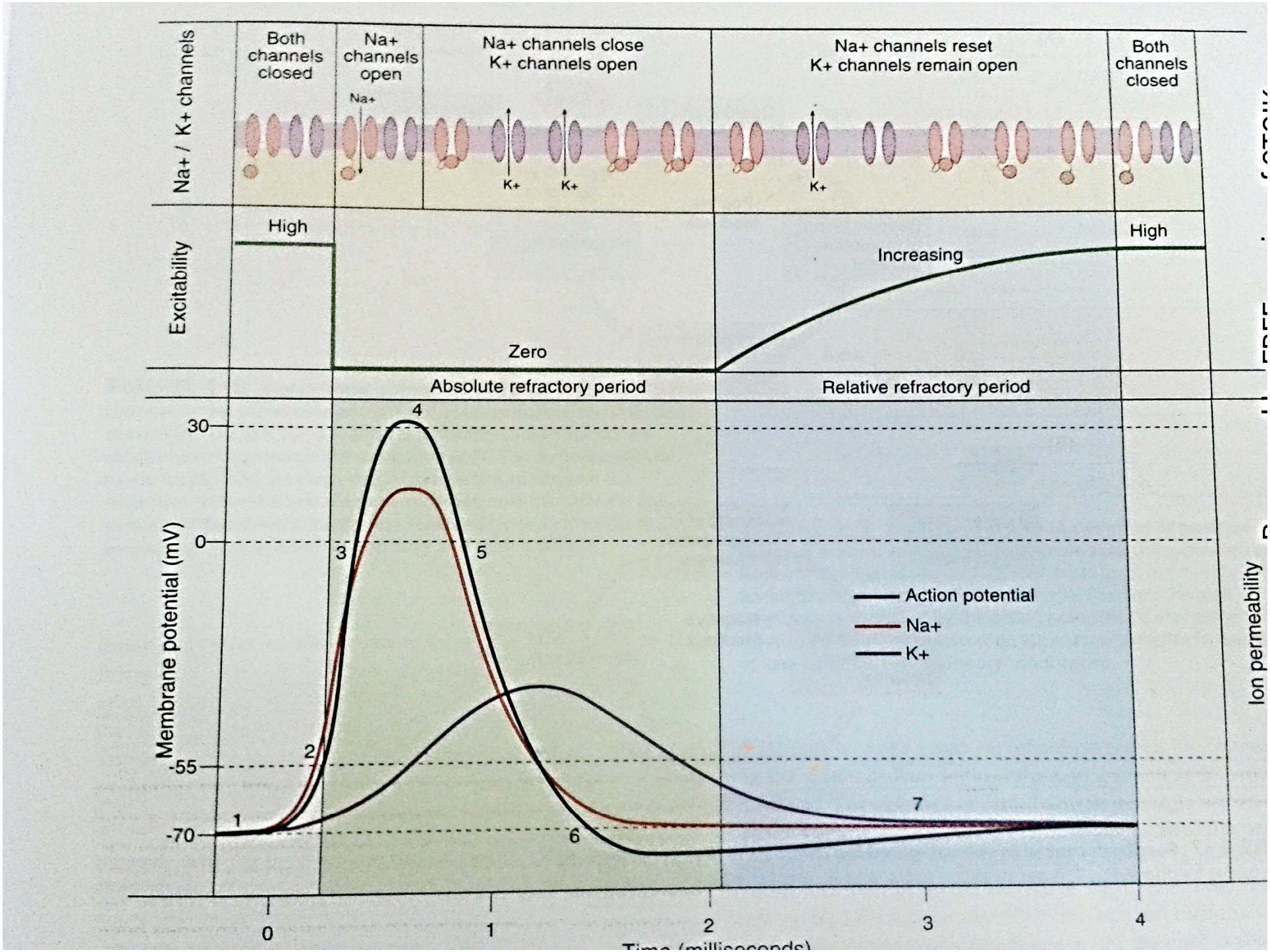
RESTING MEMBRANE POTENTIAL

- Resting Membrane Potential (RMP) is the voltage (charge) difference across the cell membrane when the cell is at rest.
- RMP is a product of the distribution of charged particles (ions).
- There are positively charged ions called cations (e.g., Na^+, K^+, Mg^{2+}, Ca^{2+}) and negatively charged ions called anions (e.g., Cl^- and proteins that act as anions).



RESTING MEMBRANE POTENTIAL




Na+ / K+ channels
Both channels closed
Na+ channels open
Na+
Na+ channels close
K+ channels open
K+
K+
Na+ channels reset
K+ channels remain open
K+
Both channels closed
Excitability
High
Zero
Increasing
High
Absolute refractory period
Relative refractory period
Membrane potential (mV)
30
0
-55
-70
1
2
3
4
5
6
7
Action potential
Na+
K+
Ion permeability
0
1
2
3
4

ACTION POTENTIAL

Step 1: Resting membrane potential.

Step 2: Some of the voltage-gated Na-channels open and Na enters the cell (threshold potential).

Step 3: Opening of more voltage-gated Na-channels and further depolarization (rapid upstroke).

Step 4: Reaches to peak level.

Step 5: Direction of electrical gradient for Na is reversed + Na-channels rapidly enter a closed state "inactivated state" + voltage – gated **K-channels** open (start of repolarization).

Step 6: Slow return of K-channels to the closed state (after-hyperpolarization).

Step 7: Return to the resting membrane potential.

ACTION POTENTIAL

- Decreasing the external **Na** concentration has little effect on RMP, but reduces the *size of action potential.*
- Hyperkalemia: neuron becomes more ***excitable.***
- Hypokalemia: neuron becomes ***hyperpolarized***.
- Hypocalsemia: ***increases*** the excitability of the nerve.
- Hypercalsemia: ***decreases*** the excitability.

ACTION POTENTIAL

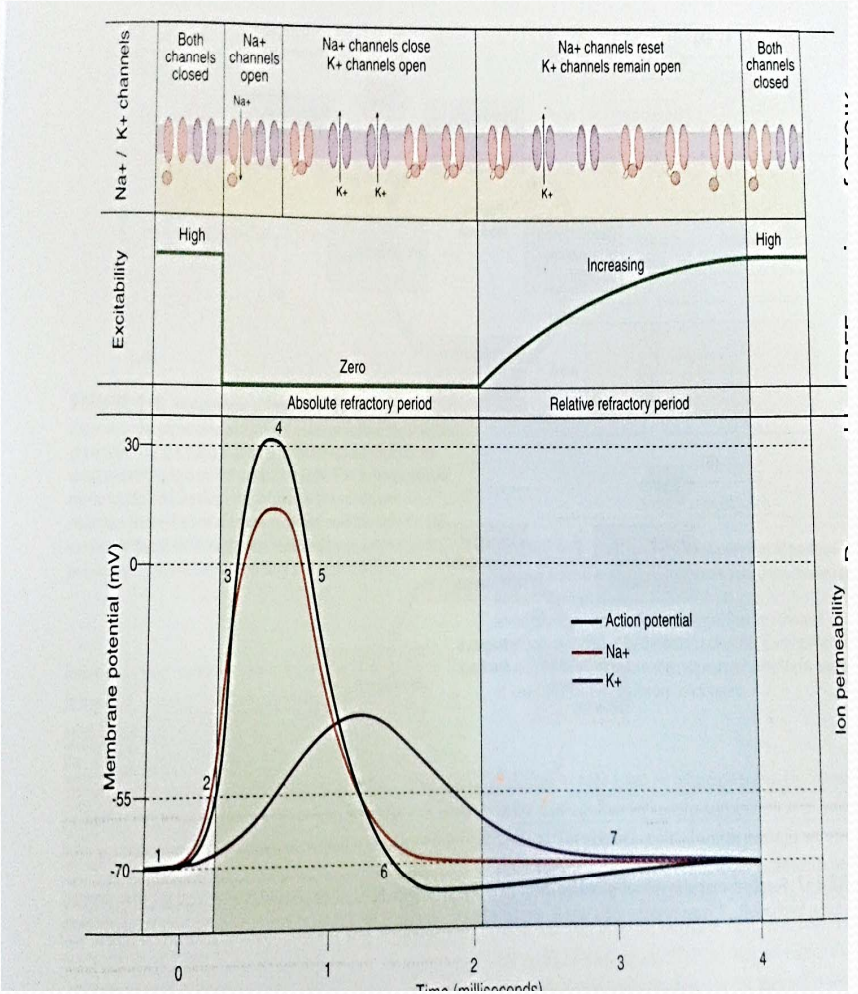
- Once threshold intensity is reached, a full action potential is produced.
- The action potential fails to occur if the stimulus is sub threshold in magnitude.
- Further increases in the intensity of the stimulus produce no other changes in the action potential.
- So, the action potential is **all or none** in character.

ALL OR NONE LAW

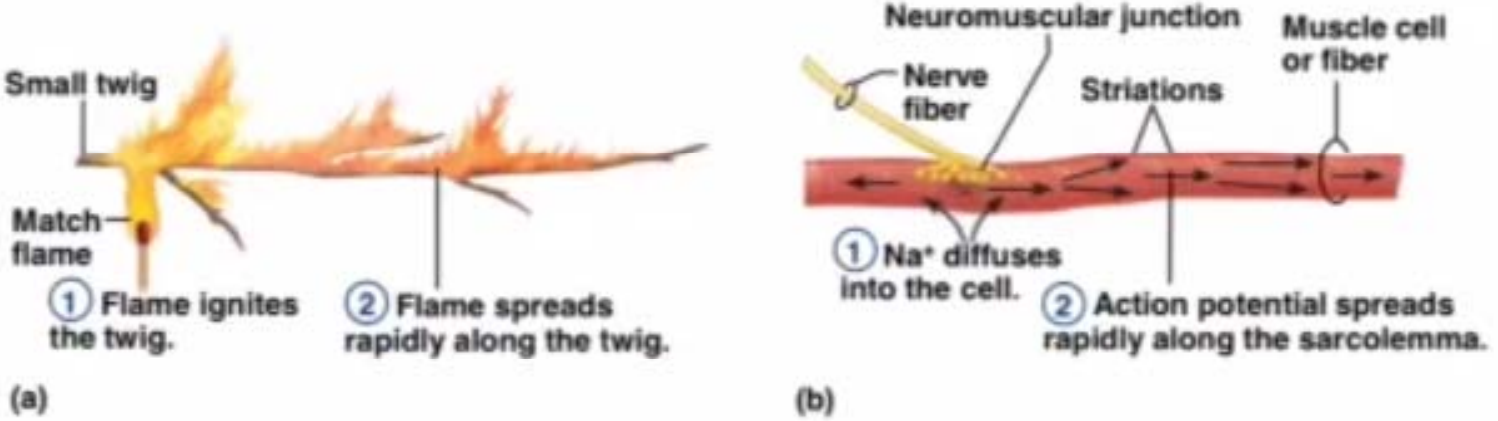
- The all-or-none law is a principle that states, that the strength of a response of a nerve cell or muscle fiber is not dependent upon the strength of the stimulus. If a stimulus is above a certain threshold, a nerve or muscle fiber will fire. Essentially, there will either be a full response or there will be no response at all.

ACTION POTENTIAL

- Absolute refractory period: From the time the threshold potential is reached until repolarization is about one-third complete.
- Relative refractory period: From the end of absolute refractory period to the start of after–depolarization.



FLOW OF ACTION POTENTIAL



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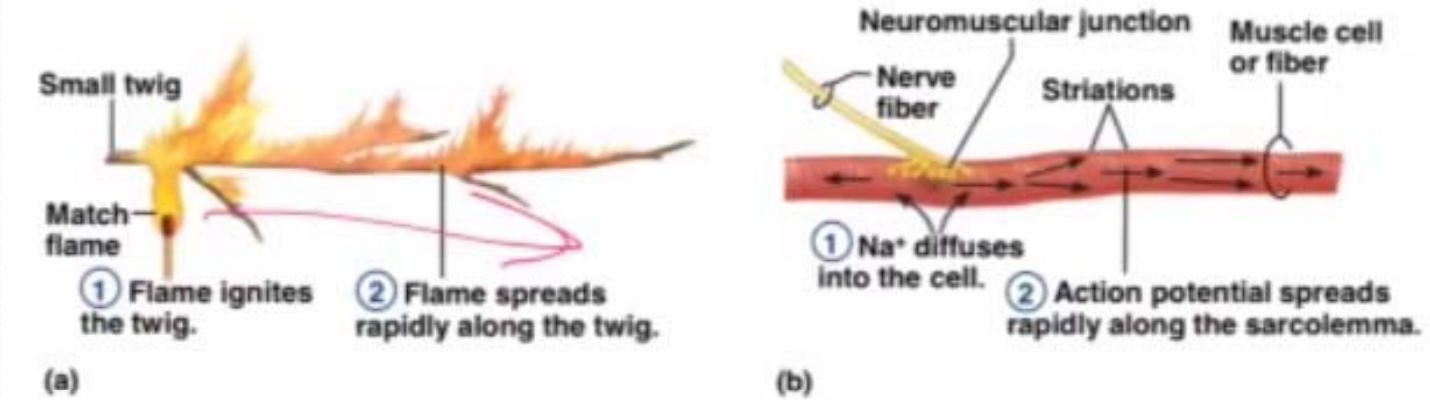

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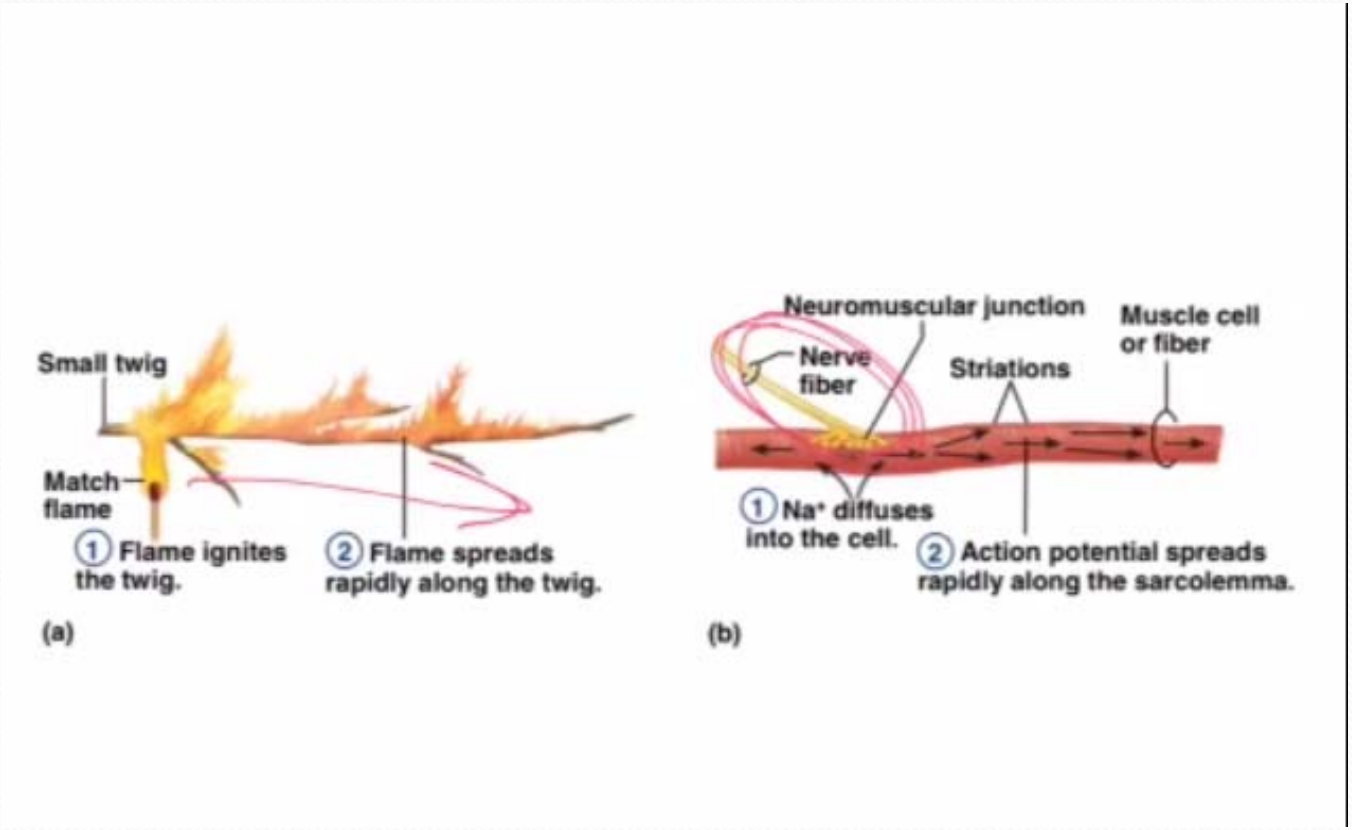

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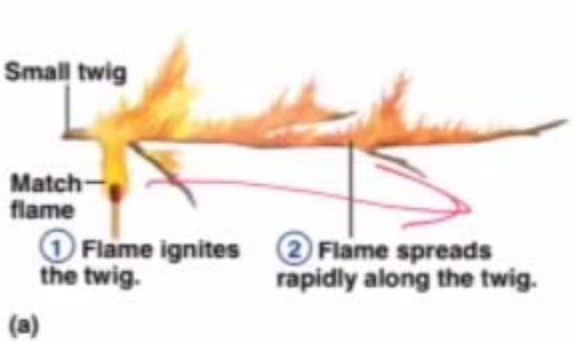
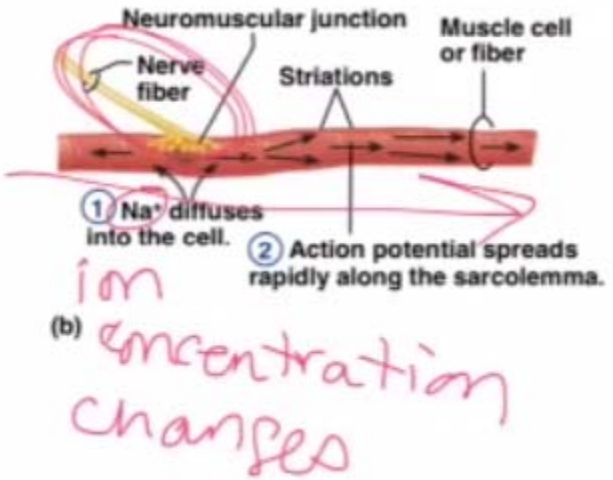
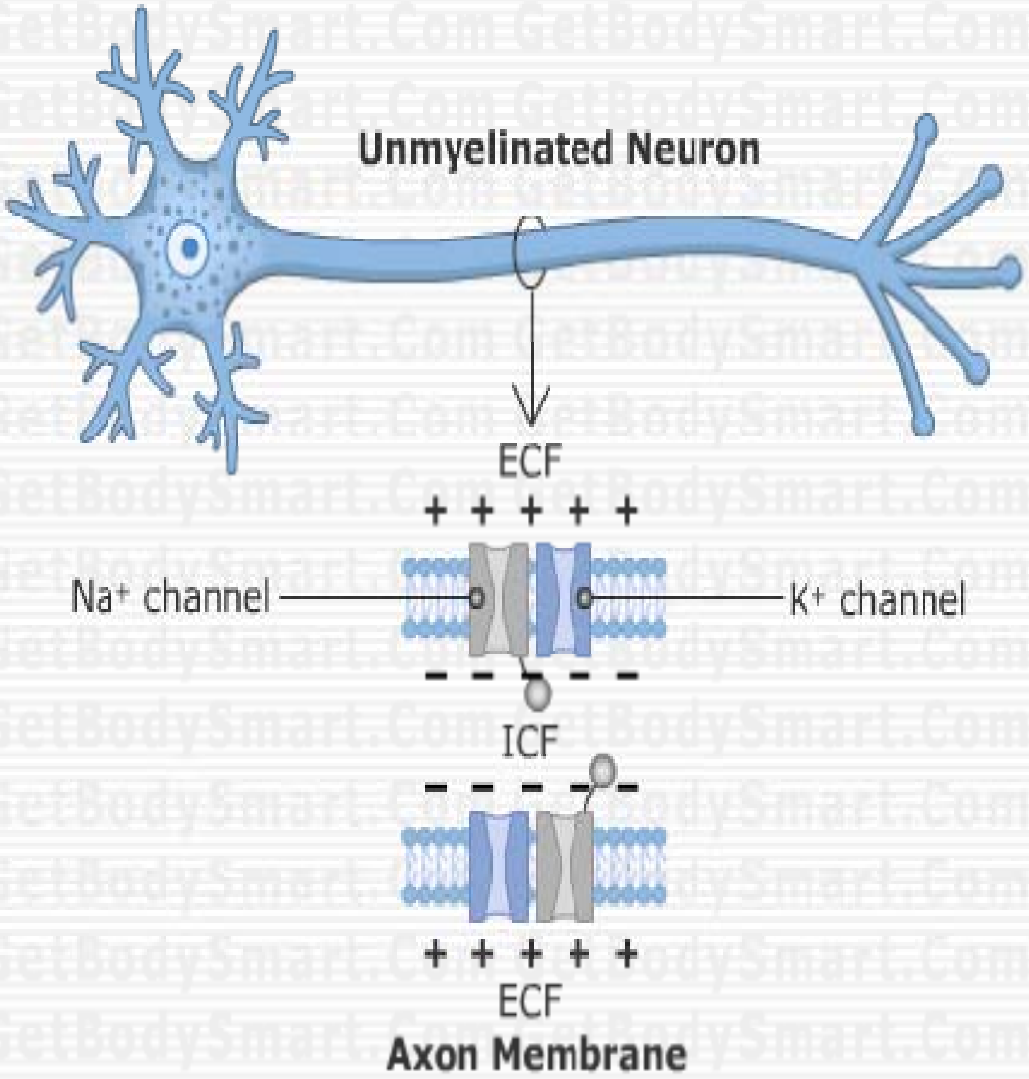




ion concentration changes

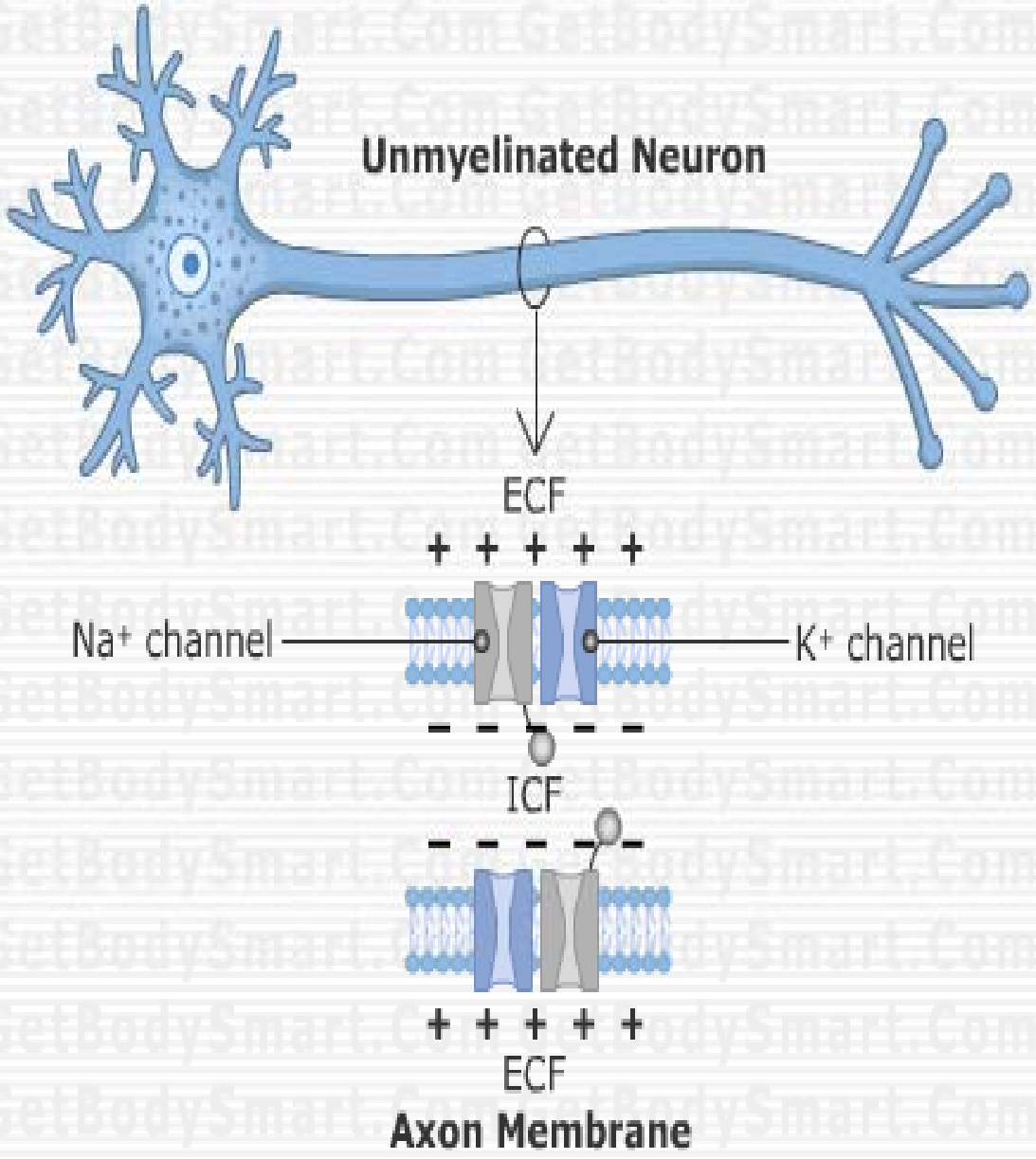
CONDUCTION of the ACTION POTENTIAL



An action potential is a rapid depolarization and repolarization of a small portion of the axon membrane.

The membrane depolarizes when **Na^+ channels open** and Na^- ions diffuse into the axon. It quickly repolarizes when **K^+ channels open** and K^+ exit the axon.

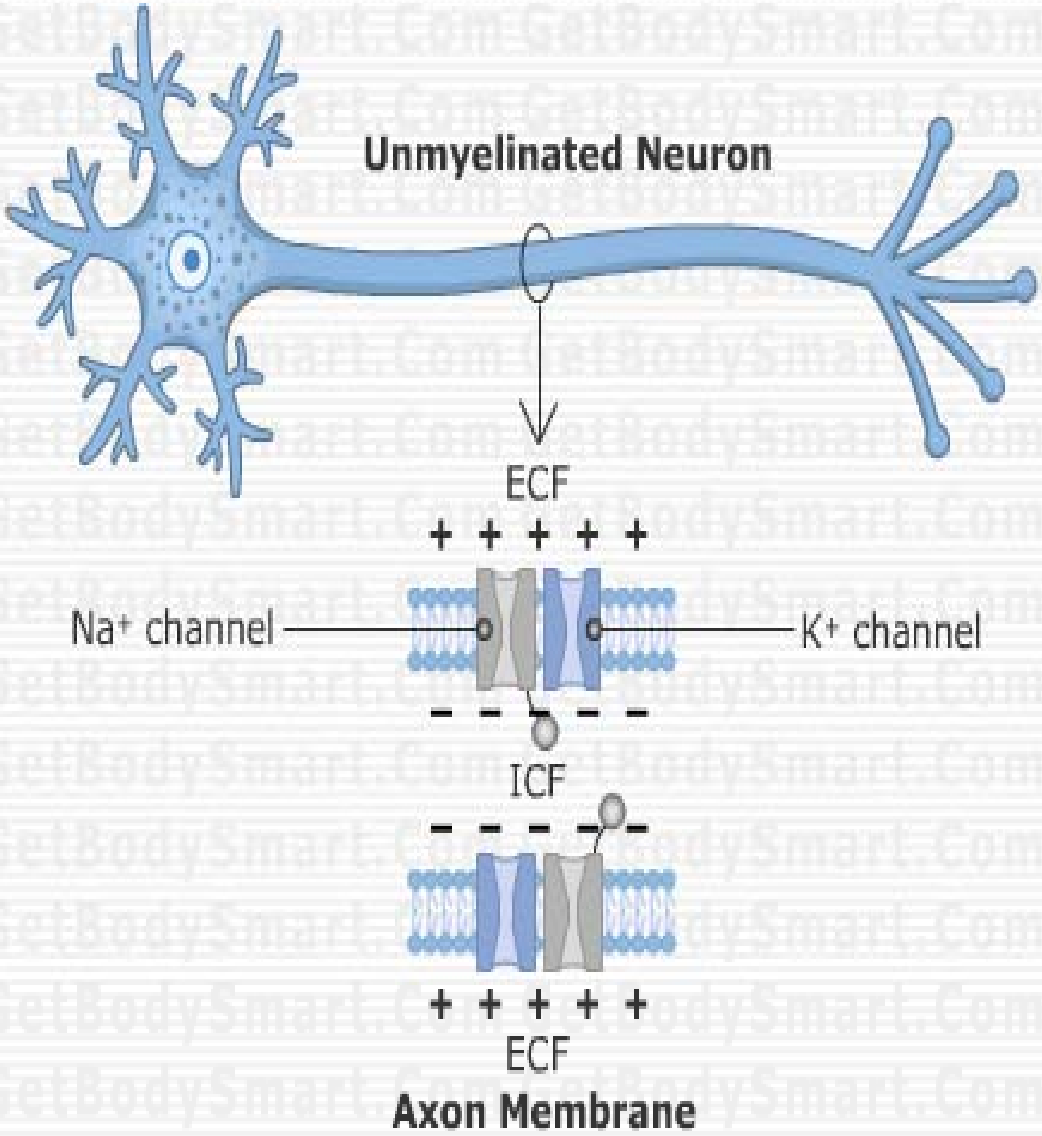
The **first action potential** usually occurs at the initial segment of the axon and is initiated by a theshold stimulus from the dendrites and cell body (= *soma*).



Because each action potential impacts only a part of the membrane, a series of action potentials is required to **propagate** (= *conduct*) a signal along the entire length of an axon.

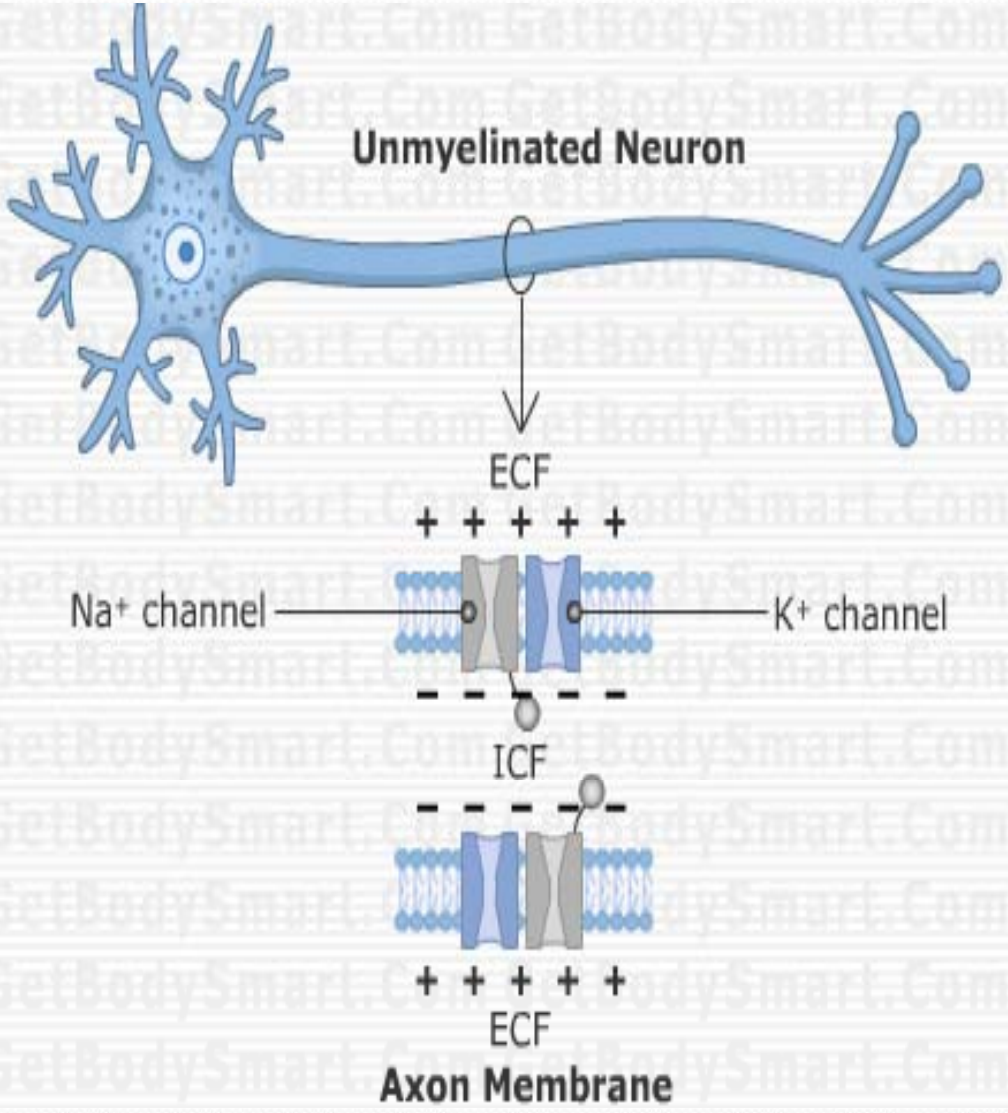
Each action potential is triggered by the **spread of passive current** (= local potentials; electrotonic potentials) generated by the previous action potential.

A current develops when Na^+ ions enter the axon and the area reverse polarizes. Oppositely charged ions are



attracted to one another (= *current*), which alters the membrane potential around nearby channels. When the membrane potential reaches threshold, the nearby Na^+ channels open and the cycle of action potential **propagation continues**.

The electrotonic currents spread in both directions. However, they do not affect the previous portion of the axon membrane because the Na^+ channels in this area are refractory (= nonresponsive) and cannot re-open until the membrane is completely

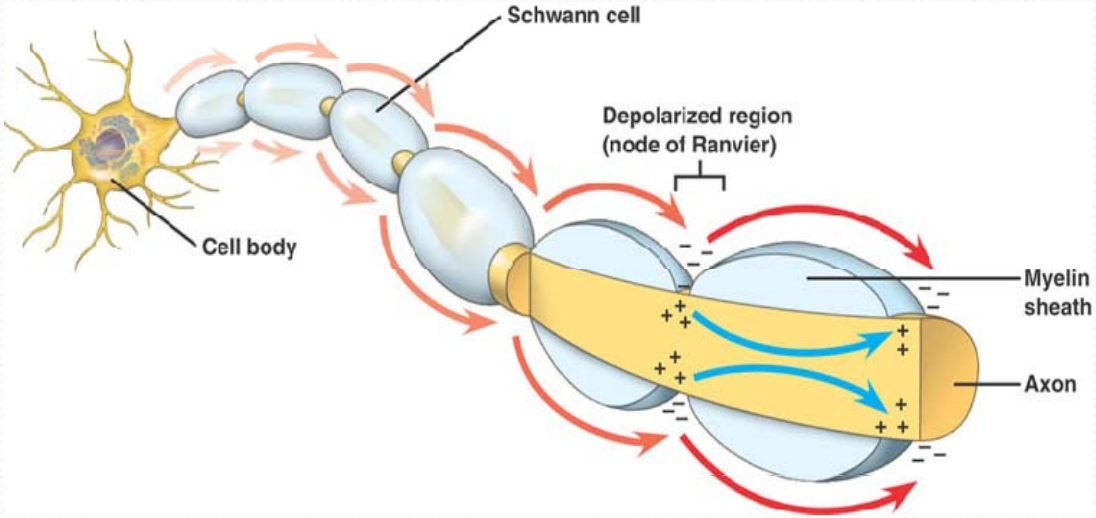


repolarized.

In unmyelinated axons, electrotonic currents decay rapidly over as they spread. This occurs because much of the current leaks through the unmyelinated membrane.

CONDUCTION of the ACTION POTENTIAL

- Myelinated axon:
  - Myelin is an effective insulator.
  - Depolarization travels from one node of Ranvier to the next.
  - This jumping of depolarization from node to node is called "saltatory conduction"
  - Faster than unmyelinated axons.



ORTHODROMIC & ANTIDROMIC CONDUCTION

- Orthodromic: From synaptic junctions or receptors along axons to their termination.
- Antidromic: The opposite direction (towards the soma).

NERVE FIBER TYPES & FUNCTION

FIBER TYPE	FUNCTION	FIBER DIAMETER (µm)	CONDUCTION VELOCITY (m/s)	MYELINATION
Aα	Proprioception, somatic motor	12-20	70-120	Myelinated
Aβ	Touch, pressure	5-12	30-70	Myelinated
Aγ	Motor to muscle spindles	3-6	15-30	Myelinated
Aδ	Pain, temperature	2-5	12-30	Myelinated
B	Preganglionic, autonomic	<3	3-15	Myelinated
C, Dorsal root	Pain, temperature	0,4-1,2	0,5-2	Unmyelinated
D, Sympathetic	Postganglionic sympathetic	0,3-1,3	0,7-2,3	

STRENGTH DURATION CURVE

- It shows the interdependence between stimulus strength and the time required in activating the muscles.
- It indicates the strength of impulses of various durations required to produce muscle contraction by joining the points that graphically represent the threshold value along the ordinate for various durations.

ADVANTAGES & DISADVANTAGES

- This is a simple, reliable and shows a proportion of denervation.√

- In large muscles it can not shows the full pictures but only a proportion of muscle fibers can be stimulated.X
- It can not show the site of lesion.X

Optimum timing of SDC:

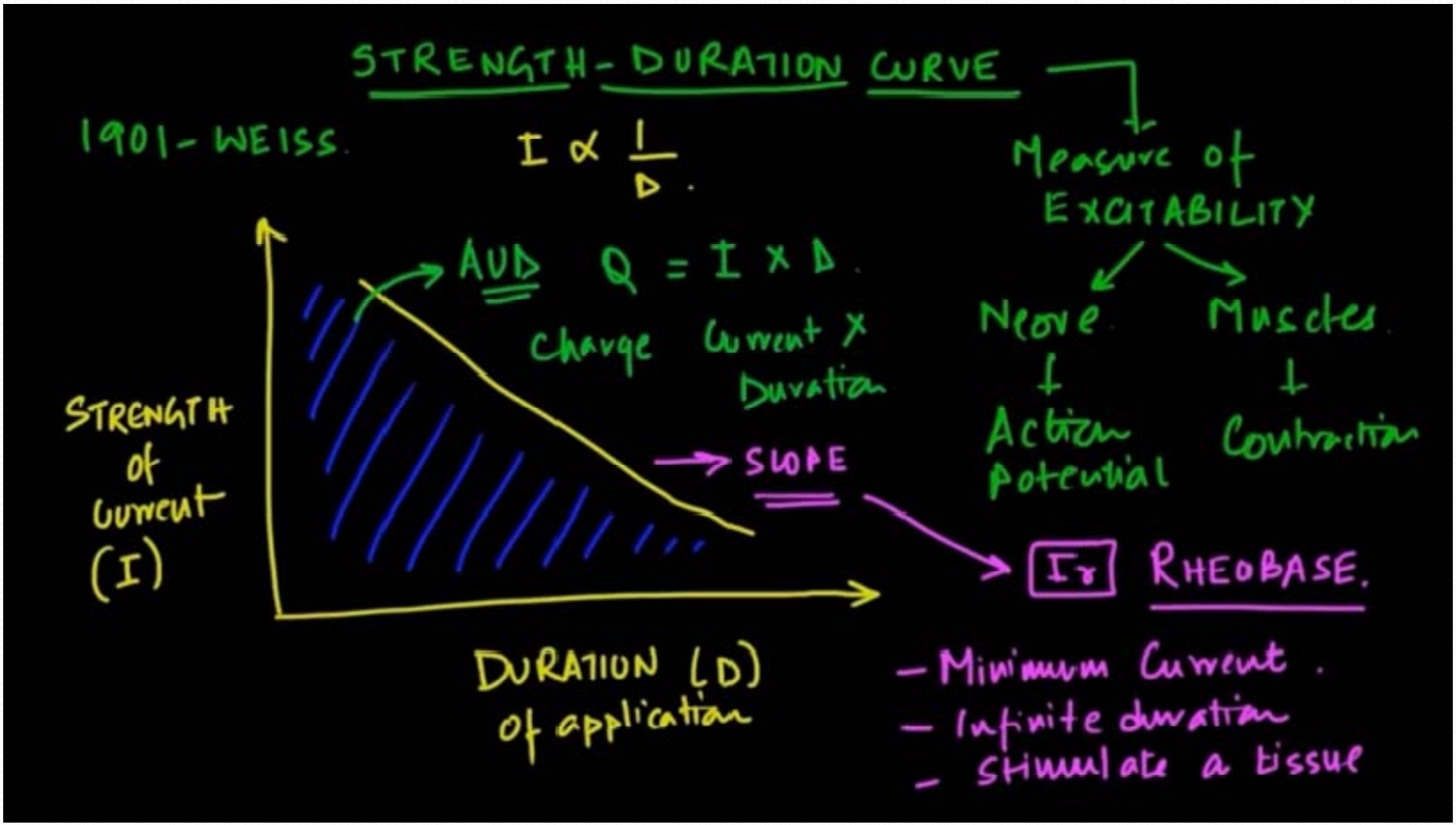
- SDC test can be done 10 – 14 days after the lesion has occurred.
- The degeneration of nerve from the proximal to distal is called Wallerian degeneration.
- When the motor end plate is no longer functioning, it is done weekly under the same condition until there is recovery and decision has been reached on the eventual final state of the muscle.
- SDC is used to identify denervation, partial innervation, and compression.

Methods of SDC:

- Take a neuromuscular stimulator (TENS, DL-2-stimulator) having rectangular duration i.e. 0.3, 0.1, 1, 3, 10, 30, 100, 300 ms and constant current.
- Put the passive electrode over the midline of the body or near the origin of the muscle.
- Put the active electrode over the fleshy belly of the muscle.

- Alternately both the electrodes are placed on both ends of the muscle.
- First apply current having longest duration and look for minimum perceptible contraction, gradually shorten the impulse duration and note the corresponding increase in current strength.
- The electrode placement should not be changed through out the test.
- Plot a SD graph from the results of the test.

STRENGTH DURATION CURVE



Weiss model : - too simple
- Actual tissues : SD curve is not LINEAR.

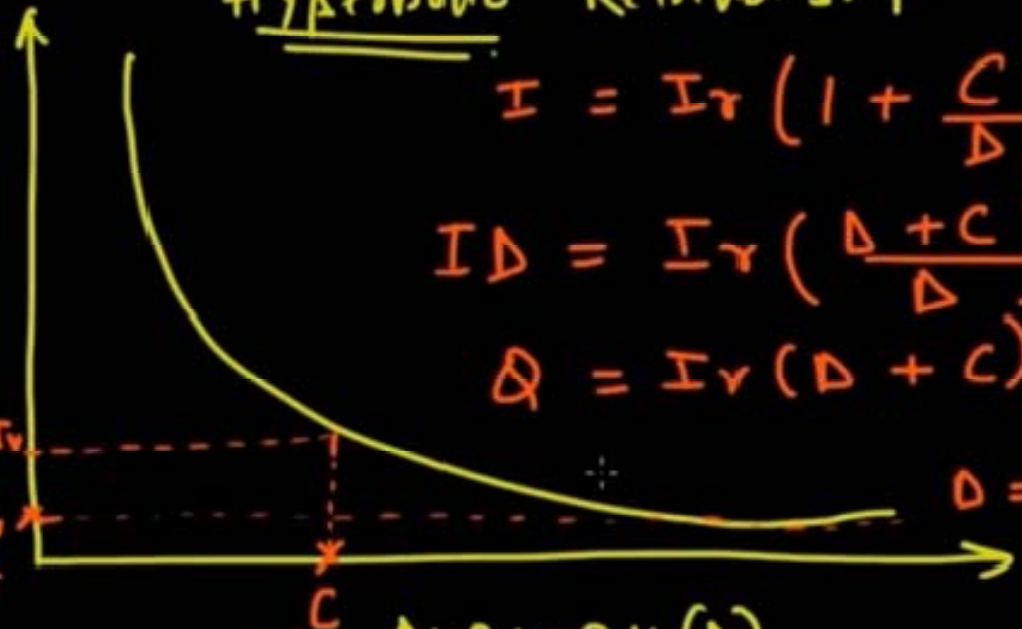
1909: LAPICQUE

Hyperbolic Relationship

$$I = I_r \left(1 + \frac{C}{D}\right)$$

$$ID = I_r \left(\frac{D + C}{D}\right) \times D$$

$$Q = I_r (D + C)$$

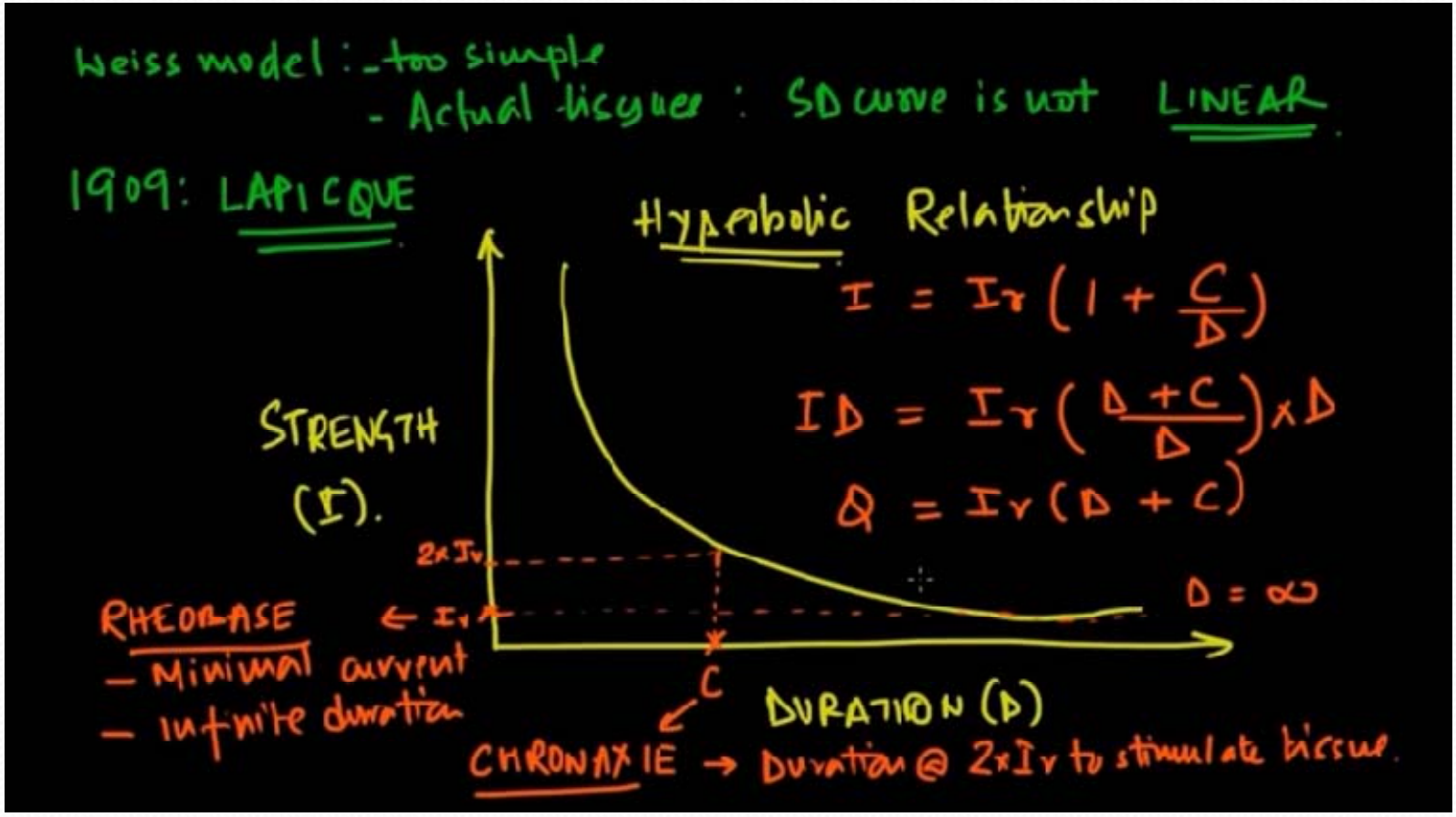


RHEOBASE
- Minimal current
- Infinite duration

CHRONAXIE → Duration @ 2×Iv to stimulate tissue.

Innervated Muscle

- When all the nerve fibers supplying the muscles are intact, the strength duration curve has a shape characteristic of normally innervated muscles as shown in the figure.
- The same strength of stimulus is required to produce a response with all the impulses of longer duration, while those of shorter duration require an increase in strengths of the stimulus each time the duration is reduced.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Hyperbolic Relationship
$I = I_r\left(1 + \frac{C}{D}\right)$
$ID = I_r\left(\frac{D+C}{D}\right) \times D$
$Q = I_r(D + C)$
STRENGTH (I).
$2 \times I_r$
I_r
RHEOBASE
- Minimal current
- Infinite duration
$D = \infty$
C
DURATION (D)
CHRONAXIE → Duration @ $2 \times I_r$ to stimulate tissue.

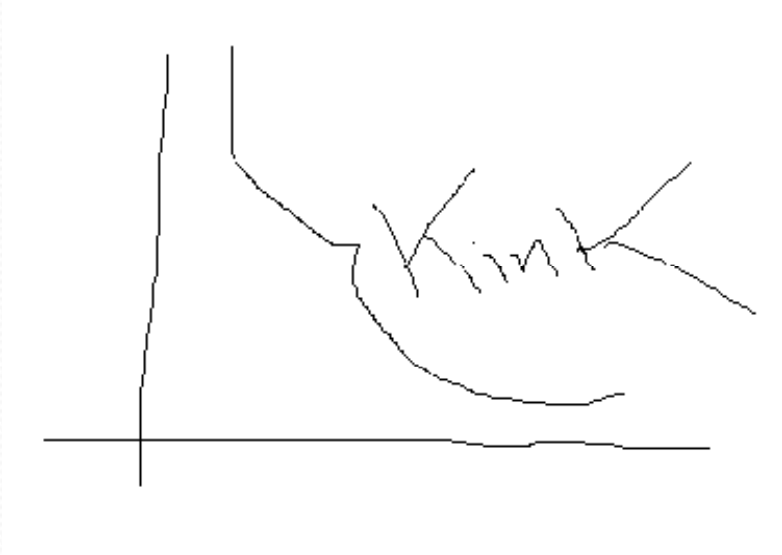
Denervated muscles:

- When all the nerve fibers supplying a muscle have degenerated, the strength duration produced is characteristic of complete denervation as shown in the figure.
- For all impulses with duration of 100 ms or less the strength of the stimulus must be increased each time the duration is reduced and no response is obtained to impulses of very short duration. The curve rises steeply and is shifted to the right than that of normally innervated muscle.


RIGHTWARD
SHIFT
↓ Sensitivity

Partial denervated muscles:

- The kink produce show the partial denervation



Factors affecting Rehobase & Chronaxie

1. Ion channels Na^+ & K^+

   main

2. Activity of sodium potassium ATP ase;

   If decreases → intracellular Na increases

   ↓

   Transmembrane Na gradient decreases

   ↓

   sensitivity decreases

3.Temperature.

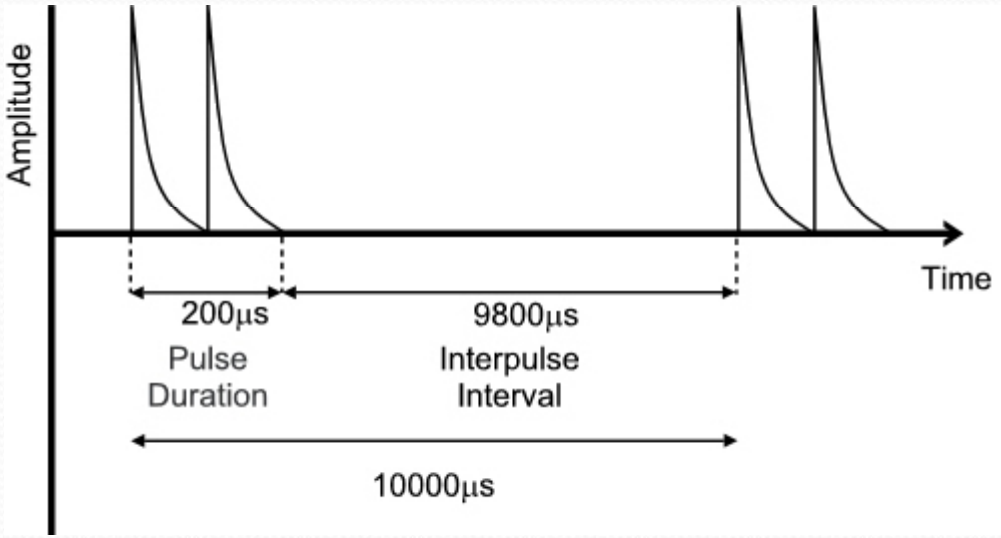
4.Demyelination there will be right ward shift of curve.

STIMULATION FOR WOUND HEALING

- The use of an electrical current to transfer energy to a wound

Wave form:

Monophasic twin peaked High Voltage Pulsed Current (HVPC)



- The pulse width varies with a range from 20-200 microseconds.
- The HVPC devices also allow for selection of polarity and variation in pulse rates both of which seem to be important in wound healing.
- It is a very safe current because it's very short pulse duration prevents significant changes in both tissue pH and temperature.
- Therefore, the most tested and safe type of stimulation is the one recommended.

Bioelectric System

- The body has its own bioelectric system.
- This system influences wound healing by attracting the cells of repair, changing cell membrane permeability ,enhancing cellular secretion through cell membranes and orientating cell structures.
- A current termed the "current of injury" is generated between the skin and inner tissues when there is a break in the skin.
- The current will continue until the skin defect is repaired.

- Healing of the injured tissue is arrested or will be incomplete if these currents no longer flow while the wound is open.
- A moist wound environment is required for the bioelectric system to function.

Rationale for applying electrical stimulation

- It mimics the natural current of injury and will jump start or accelerate the wound healing process.

Clinical Wound Healing Studies

- Early studies using direct current stimulation reported long treatment times of 20-40 hours per weeks.
- Whereas after advance & recent research studies with HVPC report a mean healing time of 9.5 weeks with 45-60 minute treatment 5-7x/wk.

Electrical stimulation affects the biological phases of wound healing in the following ways:

- **Inflammation phase**

1. Initiates the wound repair process by its effect on the current of injury.
2. Increases blood flow.
3. Promotes phagocytosis.
4. Enhances tissue oxygenation.
5. Reduces edema perhaps from reduced microvascular leakage.
6. Attracts and stimulates fibroblasts and epithelial cells.

7. Stimulates DNA synthesis.
8. Controls infection (Note: HVPC proven bacteriocidal at higher intensities than use in clinic and may not be tolerated by patient).
9. Solubilizes blood products including necrotic tissue.

Proliferation phase

- Stimulates fibroblasts and epithelial cells.
- Stimulates DNA and protein synthesis.
- Increases ATP generation.
- Improves membrane transport.
- Produces better collagen matrix organization,
- Stimulates wound contraction.

Epithelialization phase

- Stimulates epidermal cell reproduction and migration
- Produces a smoother, thinner scar

INDICATIONS FOR THE THERAPY

- Pressure Ulcers Stage I through IV
- Diabetic ulcers due to pressure, insensitivity and dysvascularity
- Venous Ulcers
- Traumatic Wounds
- Surgical Wounds
- Ischemic Ulcers
- Vasculitic Ulcers
- Donor Sites
- Wound Flaps
- Burn wounds

Protocol for treatment

- Wound Healing Phase Diagnosis: Inflammation phase

- Expected outcomes:

  Wound progresses to the Proliferation phase

- Change in Wound Healing Phase Diagnosis:

  Proliferation phase

Stimulator settings:

- Polarity - negative
- Pulse rate - 100 - 128 pps
- Intensity - 100-150 volts
- Duration - 60 minutes
- Frequency 5-7 x per week, once daily

Expected Outcomes:

- Wound progresses to Contraction and Epithelization phase.

Epithelialization phase

- *Stimulator settings:*

Polarity - alternate every three days ie 3 days negative
followed by 3 days positive

Pulse rate - 64 PPS

Intensity - 100-150 volts

Duration - 60 minutes

Frequency 5-7 x per week, once daily

Expected Outcomes:

- Wound progresses to Remodeling phase

Setting Up the Patient

- Have supplies ready before undressing the wound.
- Position patient for ease of access by staff and comfort of both.
- Remove the dressing and place in an infectious waste bag.
- Cleanse wound thoroughly to remove slough, exudate and any petrolatum products
- Sharp debride necrotic tissue, if required, before HVPC treatment

- Open gauze pads and fluff, then soak in normal saline solution, squeeze out excess liquid. An alternative is to use an amorphous hydrogel impregnated gauze. Hydrogel sheets can also be used to conduct current under the electrodes
- Fill the wound cavity with gauze including any undermined/tunneled spaces. Pack gently.
- Place an electrode over the gauze packing cover with dry gauze pad and hold in place with bandage tape.
- Connect an alligator clip to the foil.
- Connect to stimulator lead

Dispersive electrode placement:

- Usually placed proximal to the wound
- Place over soft tissues, avoid bony prominences
- Place a washcloth, wetted with water and wrung out, under the dispersive electrode
- Place against skin and hold in good contact at all edges with a nylon elasticized strap.
- If placed on the back, the weight of the body plus the strap can be used to achieve good contact at the edges

- Dispersive pad should be larger than the sum of the areas of the active electrodes and wound packing.
- The greater the separation between the active and dispersive electrode the deeper the current path. Use for deep and undermined wounds
- Dispersive and active electrodes can be close together but should not touch. Current flow will be shallow> Use for shallow, partial thickness wounds

PRECAUTIONS

- Check for skin irritation or tingling under the electrodes.
- Patients with severe peripheral vascular occlusive disease (PVD), may experience some increased pain, usually described as throbbing, in the leg after electrical stimulation.

CONTRAINDICATIONS

- Placement of electrodes tangential to the heart
- Presence of a cardiac pacemaker
- Placement of electrodes along regions of the phrenic nerve
- Presence of malignancy
- Placement of electrodes over the carotid sinus
- Placement of electrodes over the laryngeal musculature
- Placement of electrodes over topical substances containing metal ions
- Placement of electrodes over osteomyelitis


Thank You