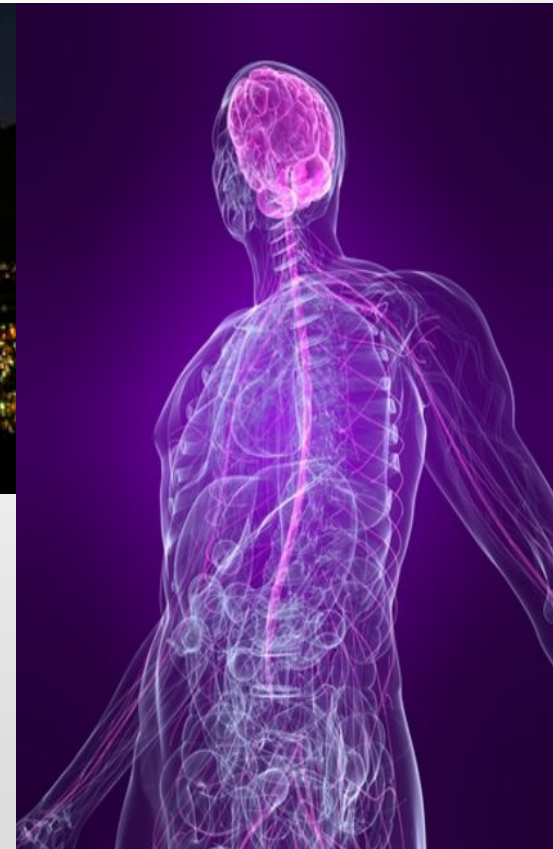
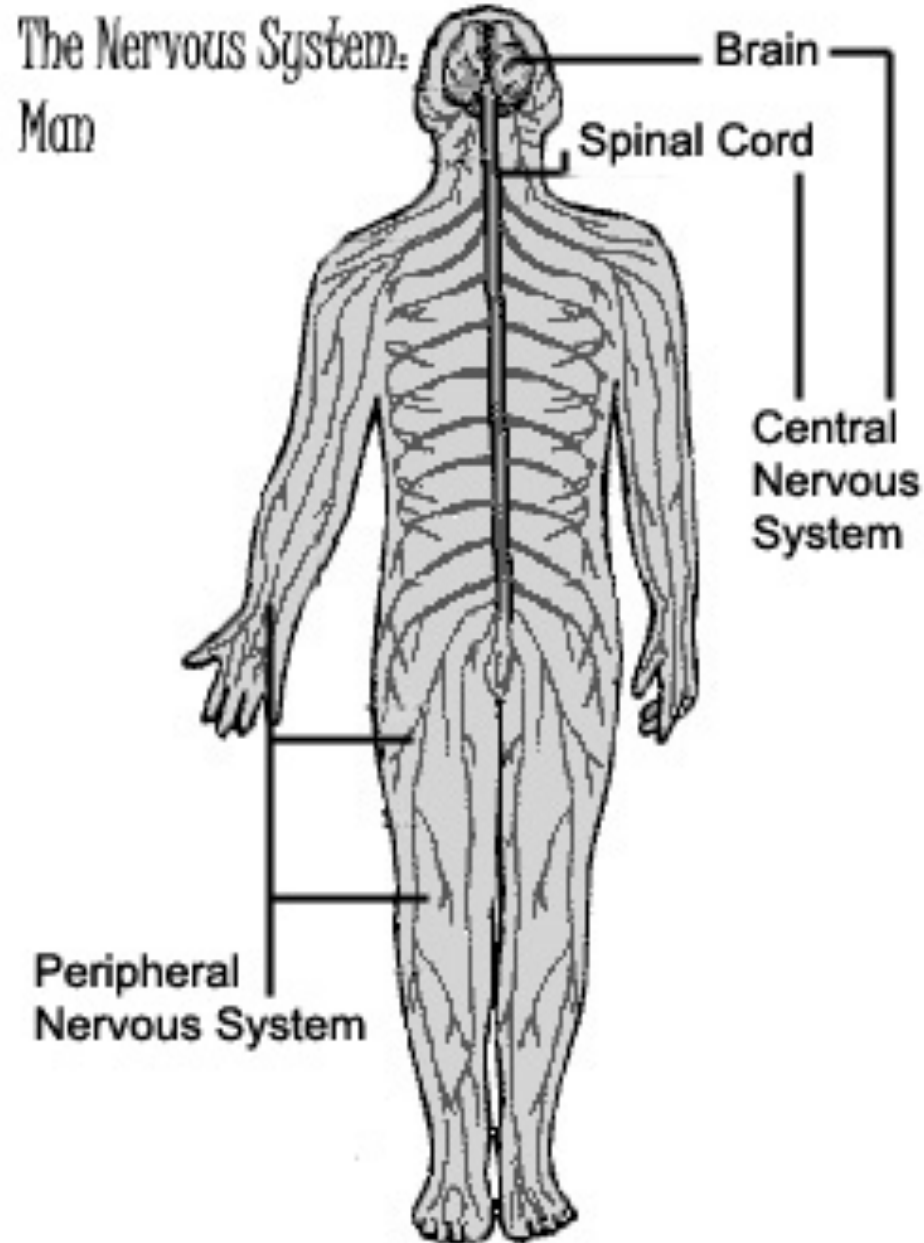


Intro to Exercise Physiology – Nervous System



Recap

- Types of Muscle
 - Skeletal/ Cardiac/ Smooth
- Sarcomeres
- Sliding Filament Theory
- Structure of Muscle



Central Nervous System

- The human brain contains approximately 100 billion individual neurons.
- Behavior depends upon the communication between neurons.

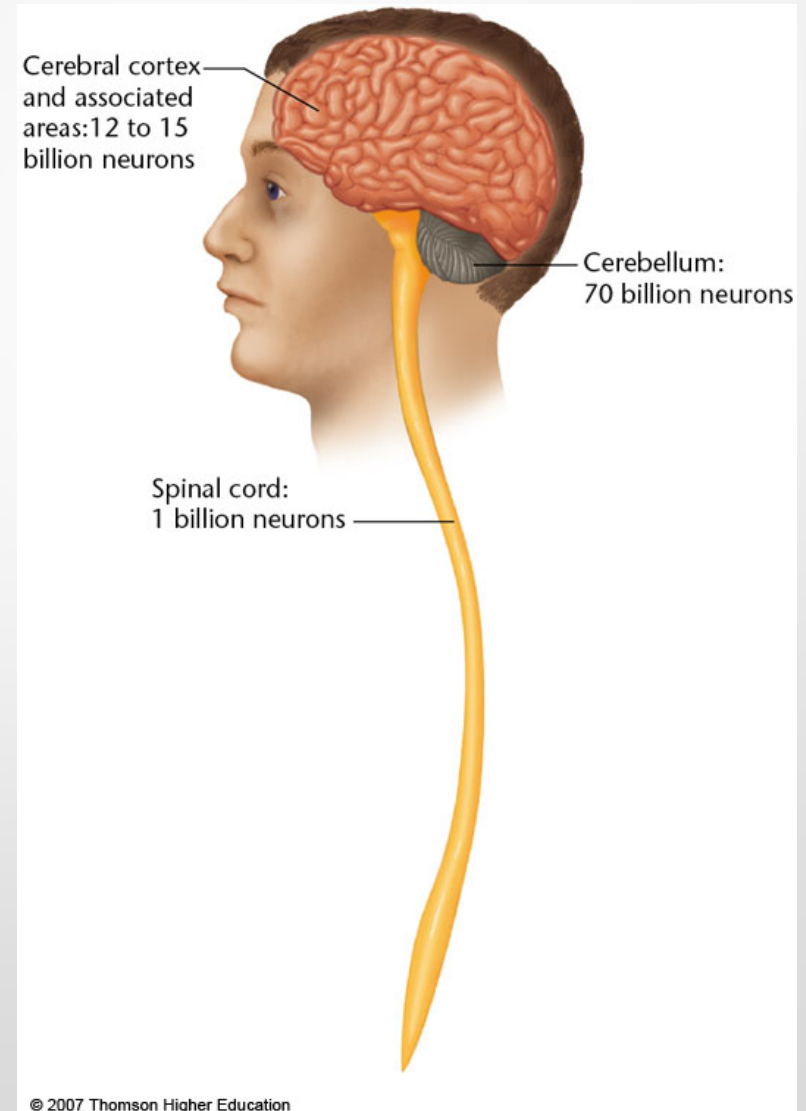


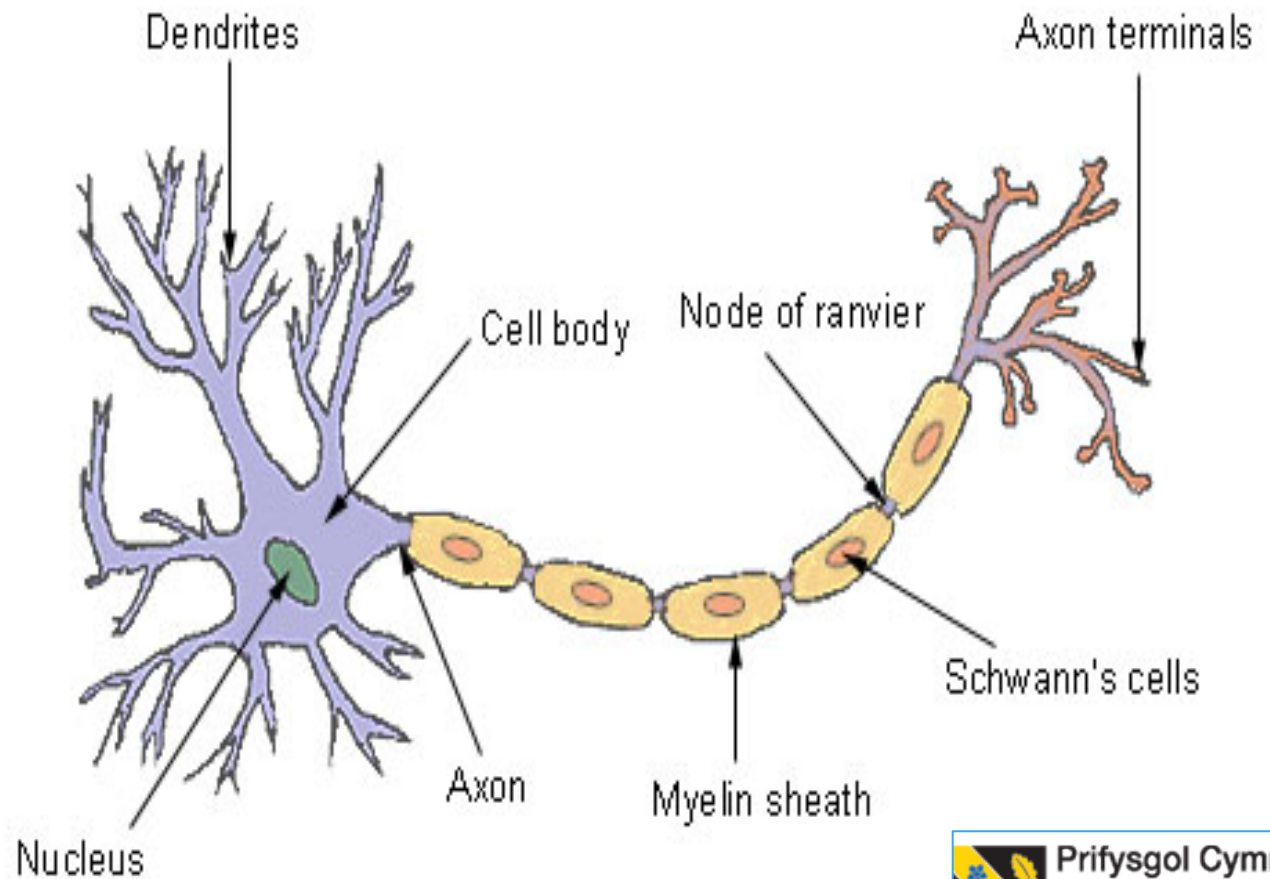
Fig. 2-1, p. 30

Neuron

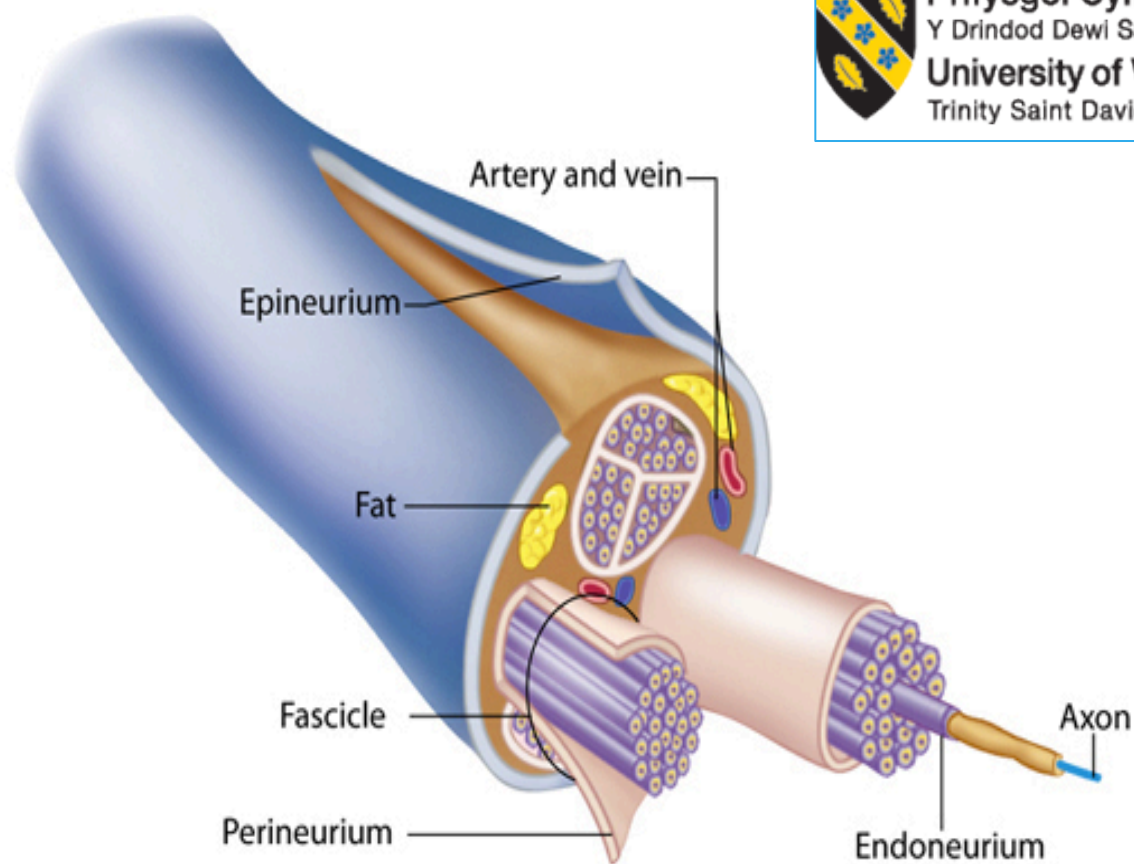
A neuron has four main parts:

- **Dendrites** - the branches of the cell where messages come in.
- **Cell body (soma)** - the main part of the cell where the main genetic and life functions take place .
- **Axon** - the branch of the neuron that carries the message (nerve impulse) to its destination.
- **Presynaptic Terminals** - refer to the end points of an axon responsible for releasing chemicals to communicate with other neurons.

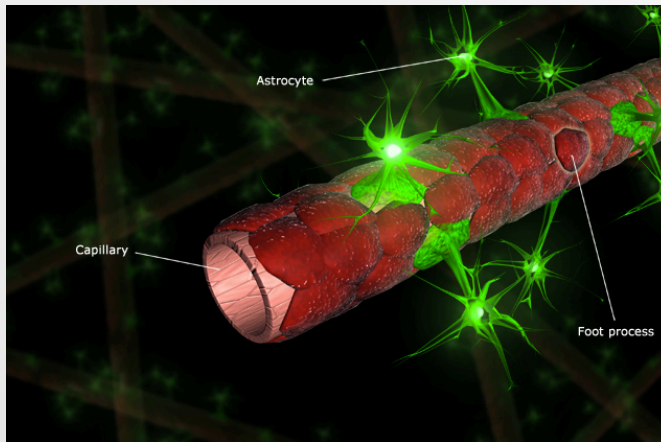
Structure of a Typical Neuron



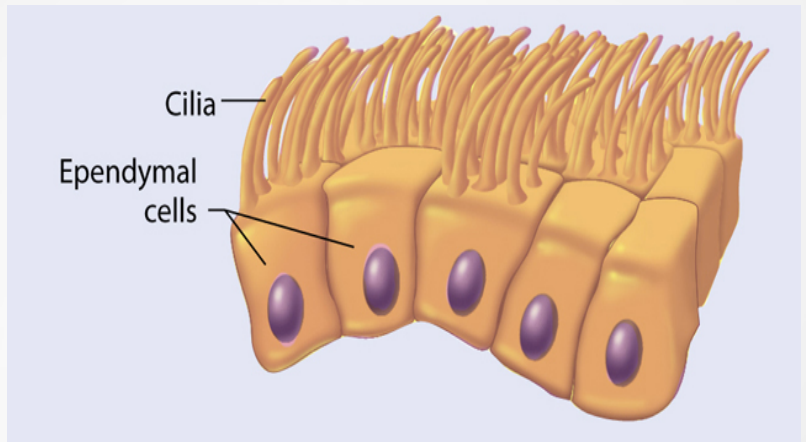
Structure of Nerves



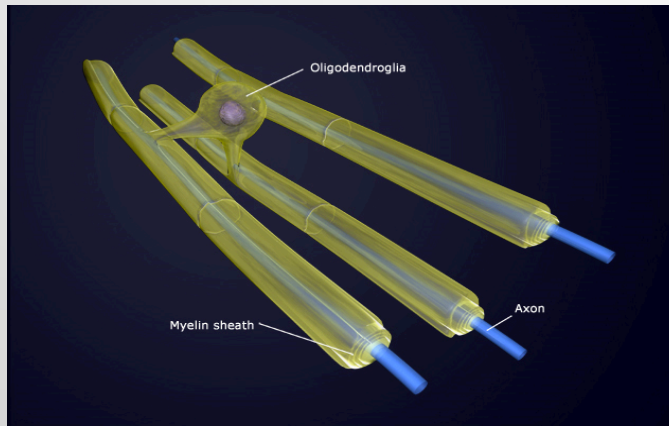
Glial – Glue cells



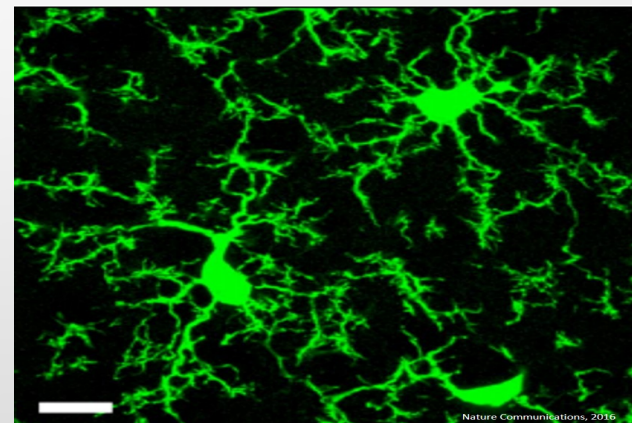
Astrocytes



Ependymal Cells



Oligodendrocytes



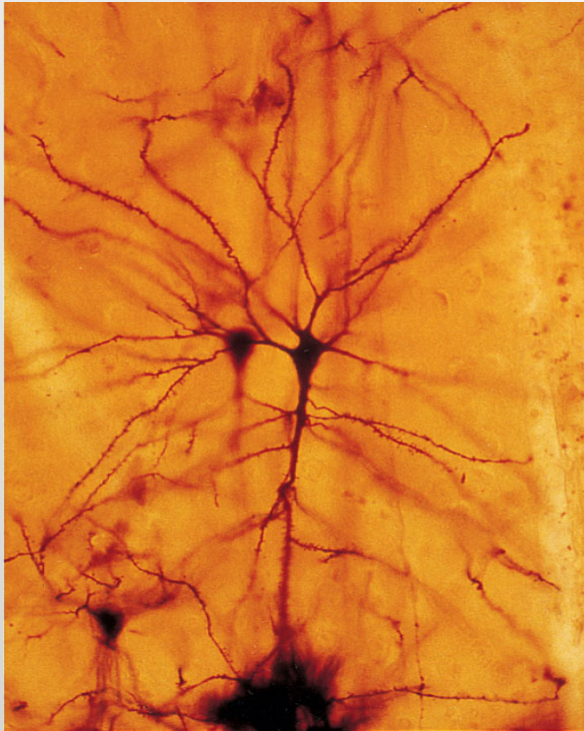
Microglia

The Cells of the Peripheral Nervous System

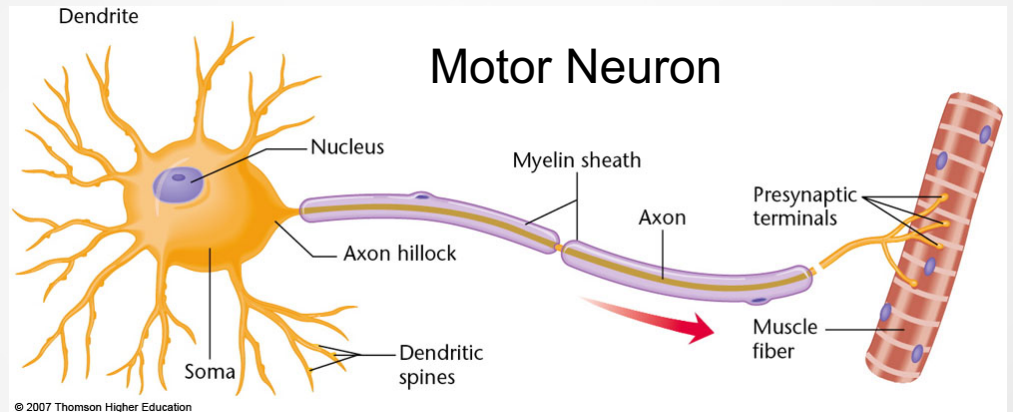
Neuron cells are similar to other cells of the body but have a distinctive shape.

- A **motor neuron** has its soma (cell body) in the spinal cord and receives excitation from other neurons and conducts impulses along its axon to a muscle.
- A **sensory neuron** is specialized at one end to be highly sensitive to a particular type of stimulation (touch, temperature, odor etc.)

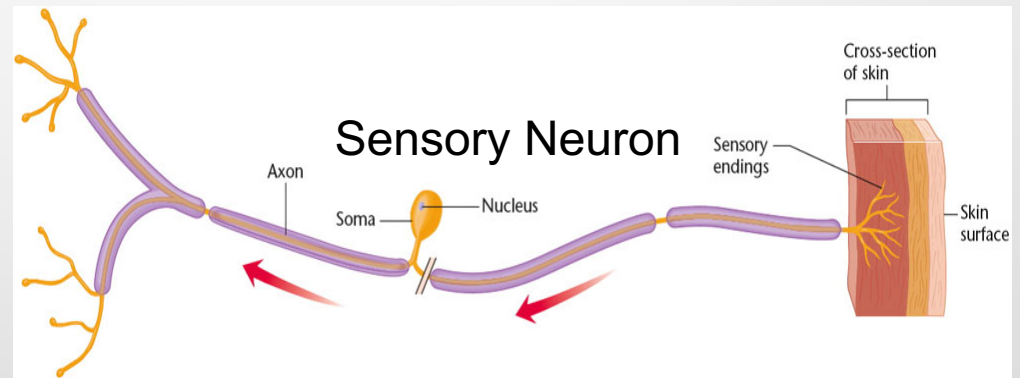
Neuron of the peripheral NS



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Peripheral NS Divisions

- **Somatic Nervous System** controlling organs under voluntary control (mainly muscles).
- **Autonomic Nervous System (ANS)** regulating individual organ function and homeostasis, and for the most part is not subject to voluntary control. It is also known as the visceral or automatic system.

Peripheral Nervous system

- 31 pairs of Spinal Nerves (leave the spinal cord between vertebrae)
- 12 pairs of Cranial Nerves (directly from organs in the head to the brain)

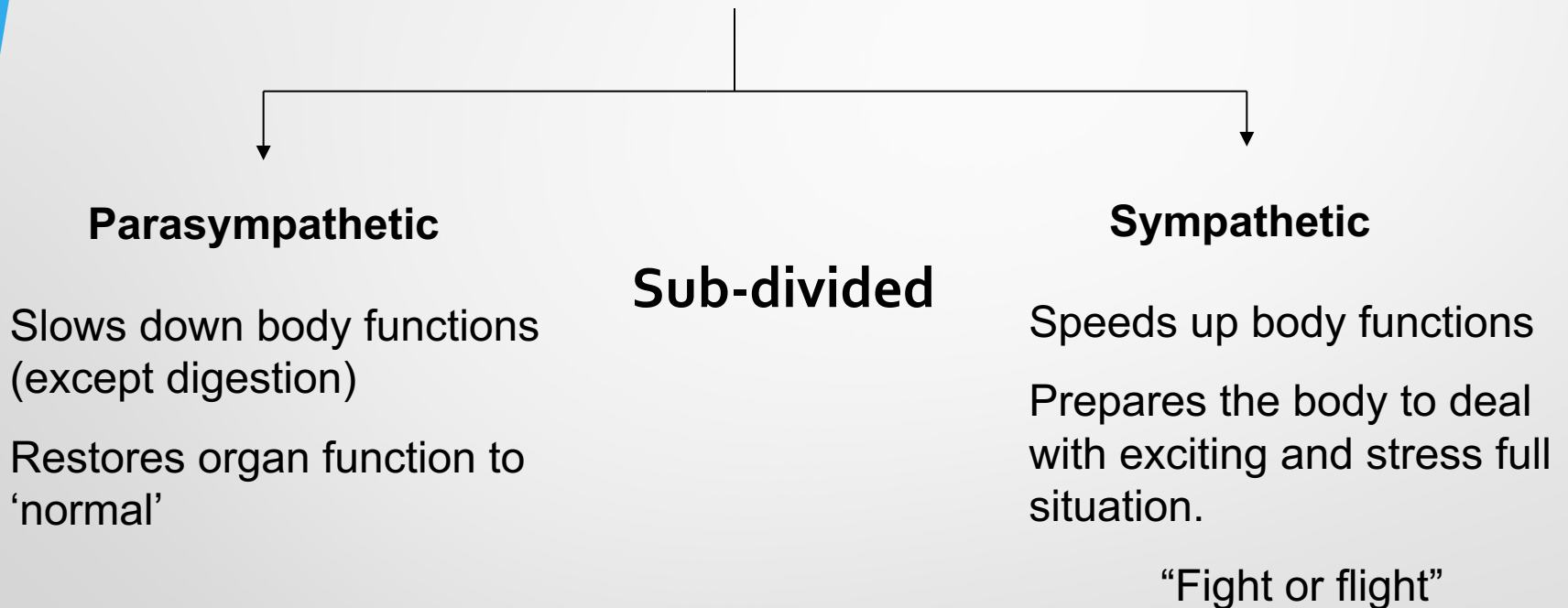
Generally comprise

1. Afferent (sensory) nerve fibres – transmit a signal from the periphery to the CNS. e.g. from eyes, pain, body position
2. Efferent (motor) nerve fibres – transmit a signal from the CNS to the periphery. e.g. to skeletal muscle

Autonomic Nervous system

- Controls functions of the body automatically
- Predominantly an efferent system transmitting impulses from the Central Nervous System (CNS) to peripheral organ systems.
 - control of heart rate
 - force of contraction,
 - constriction and dilatation of blood vessels
 - contraction and relaxation of smooth muscle
 - pupillary size
 - endocrine glands.

Autonomic Nervous system

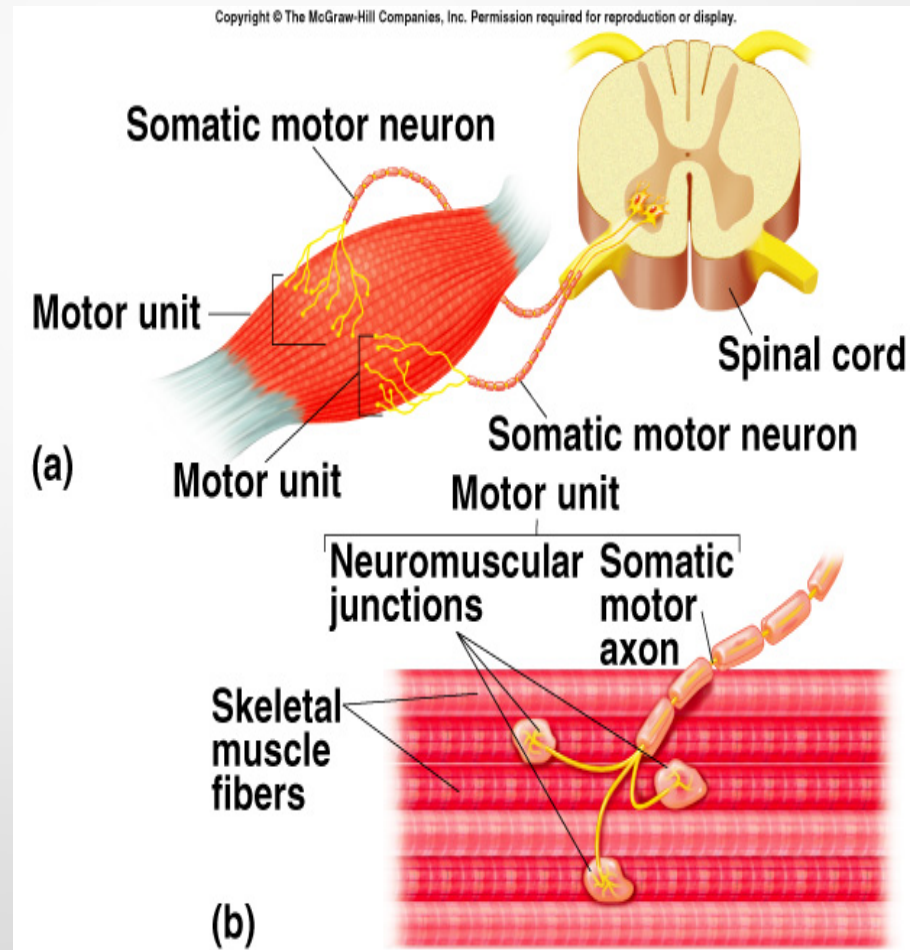


Normally the two systems function together regulating organ function in response to continually changing environmental stimuli

Organ	Sympathetic Stimulation	Parasympathetic Stimulation
Heart	Increased heart rate	Decreased heart rate
	Increased force of contraction	Decreased force of contraction
	Increased conduction velocity	Decreased conduction velocity
Arteries / Veins	Constriction in small vessels supply blood to skin	Dilation
	Dilation in vessels supplying cardiac / skeletal muscle	
Lungs	Bronchial muscle relaxation	Bronchial muscle contraction
		Increased bronchial gland secretions
Gastro-intestinal tract	Decreased motility	Increased motility
	Contraction of sphincters	Relaxation of sphincters
Liver	Glycogenolysis	Glycogen synthesis
	Gluconeogenesis	
	Lipolysis	
Kidney	Renin secretion	
Bladder	Detrusor relaxation	Detrusor contraction
	Contraction of sphincter	Relaxation of sphincter
Uterus	Contraction of pregnant uterus	
	Relaxation of pregnant and non-pregnant uterus	
Eye	Dilates pupil	Constricts pupil
		Increased lacrimal gland secretions
Submandibular & parotid glands	Viscous salivary secretions	Watery salivary secretions

The Motor Unit

- Each neuron together with all the muscle fibres it innervates.
- Each muscle fibre receives a single axon terminal from a somatic neuron.
- Each axon can have collateral branches to innervate an equal # of fibres.



Nervous Control of movement

When neuron is activated, all the muscle fibers it innervates contract with all or none contractions.

- Innervation ratio:

Ratio of motor neuron: muscle fibers.

Fine neural control over the strength occurs when many small motor units are involved.

- Recruitment:

More and more motor units need to be activated to produce greater strength.

Twitch, Summation, and Tetanus

- **Twitch:**

- Muscle is stimulated with a single electrical shock (above threshold).
 - Quickly contracts and then relaxes.
- Increasing stimulus increases the strength of the twitch (up to maximum).

- **Summation:**

- If second electrical shock is administered before complete relaxation of muscle.

- **Incomplete tetanus:**

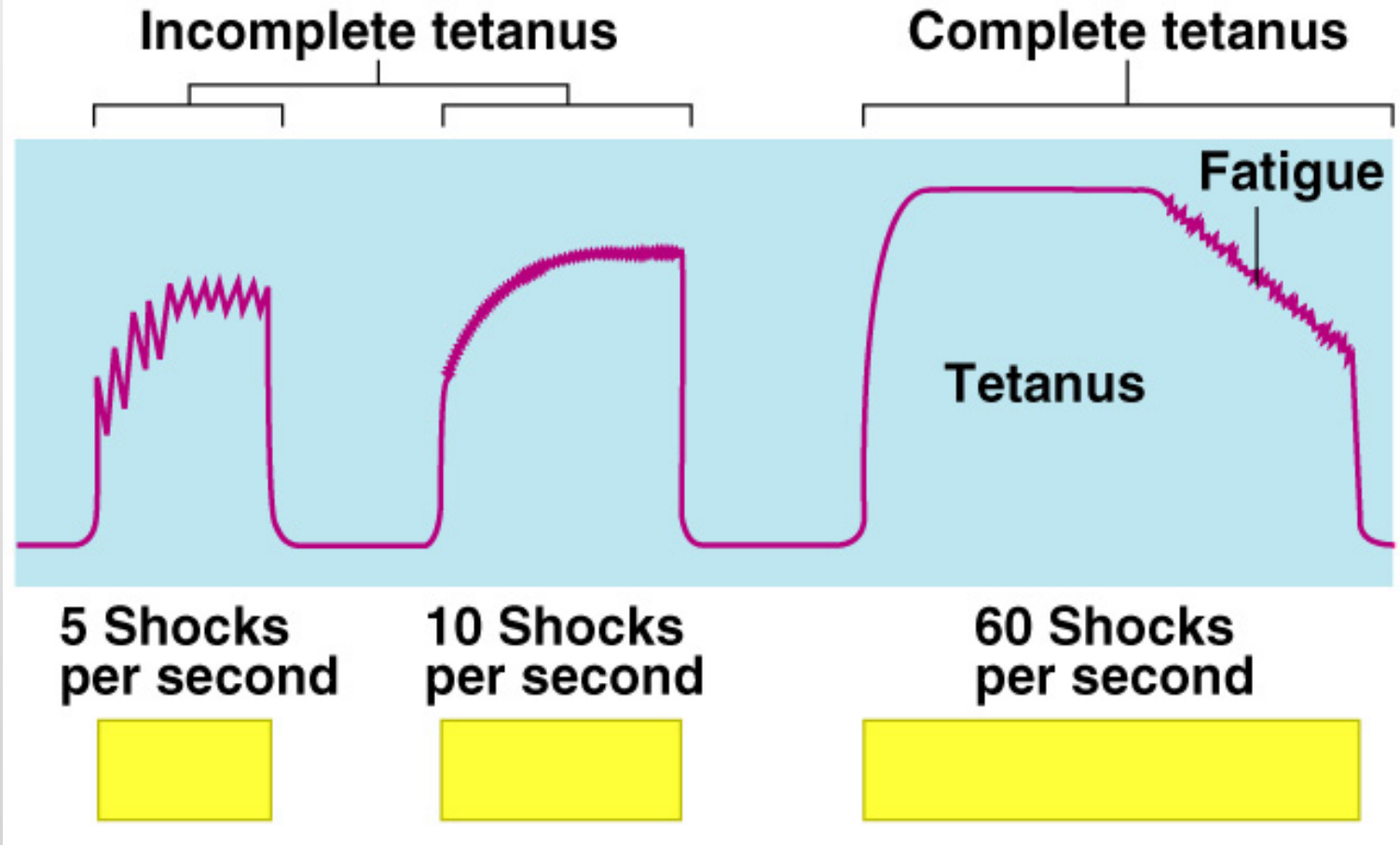
- Stimulator delivers an increasing frequency of electrical shocks.
 - Relaxation period shortens between twitches.
 - Strength of contraction increases.

- **Complete tetanus:**

- Fusion frequency of stimulation.
- No visible relaxation between twitches.
 - Smooth sustained contraction

Twitch, Summation, and Tetanus

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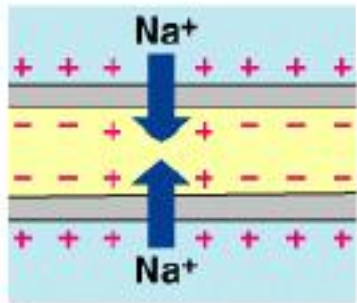
The Nerve Impulse

- A **nerve impulse** is the electrical message that is transmitted down the axon of a neuron.
- The impulse does not travel directly down the axon but is regenerated at points along the axon.
- The speed of nerve impulses ranges from approximately 1 m/s to 100 m/s.

Nature of an impulse

Messages sent throughout the body are conducted along nerves using changes in action potentials which refers to changes in the electrical charge along the nerves fibre as well as across its membrane.

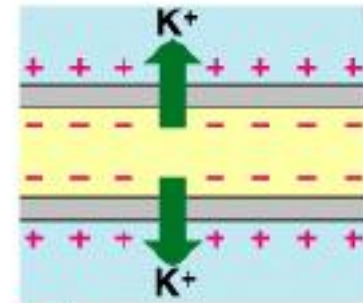
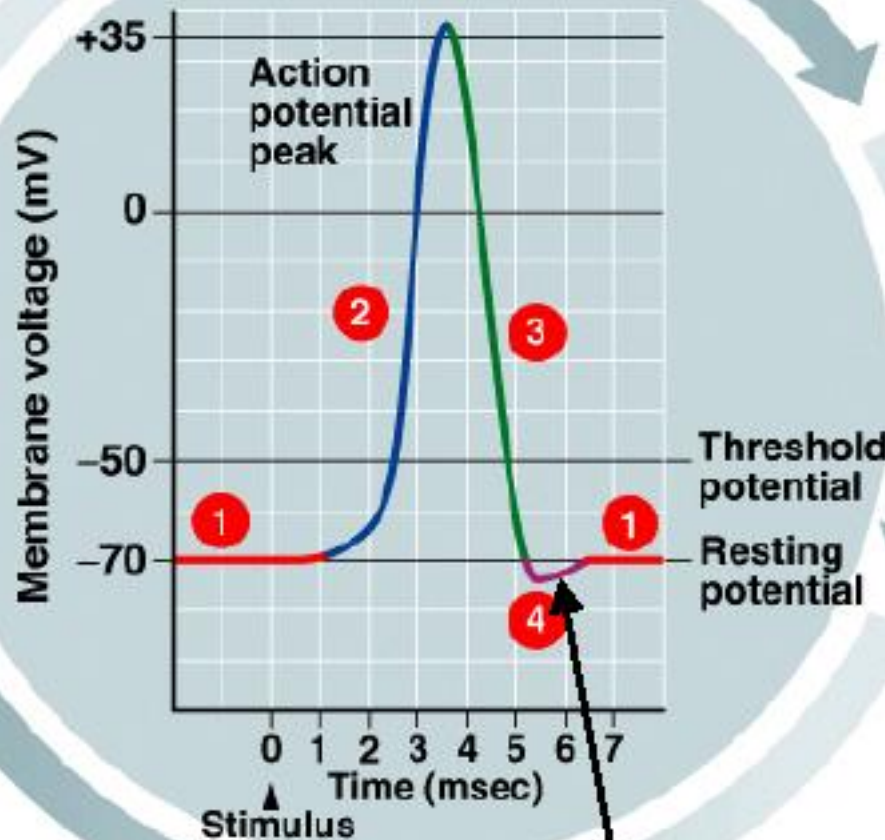
Summary of Nerve Impulse Characteristics



2 Na^+ channels open, K^+ channels are closed; threshold potential is reached and action potential is triggered.

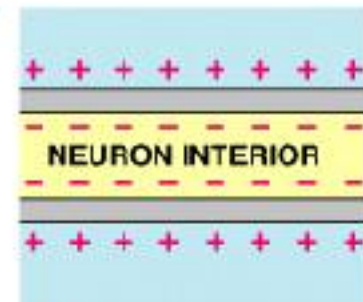


1 Resting state: no net ion flow across the membrane; voltage gated Na^+ and K^+ channels closed across the membrane; resting potential is maintained.



3 Na^+ channels close and inactivate. K^+ channels open, and K^+ rushes out.

4 The K^+ channels close relatively slowly, causing a brief undershoot.



1 Return to resting state.

Refractory period

The Nerve Impulse

- At rest, the membrane maintains an **electrical polarization** or a difference in the electrical charge of two locations.
 - the inside of the membrane is slightly negative with respect to the outside. (approximately -70 millivolts)

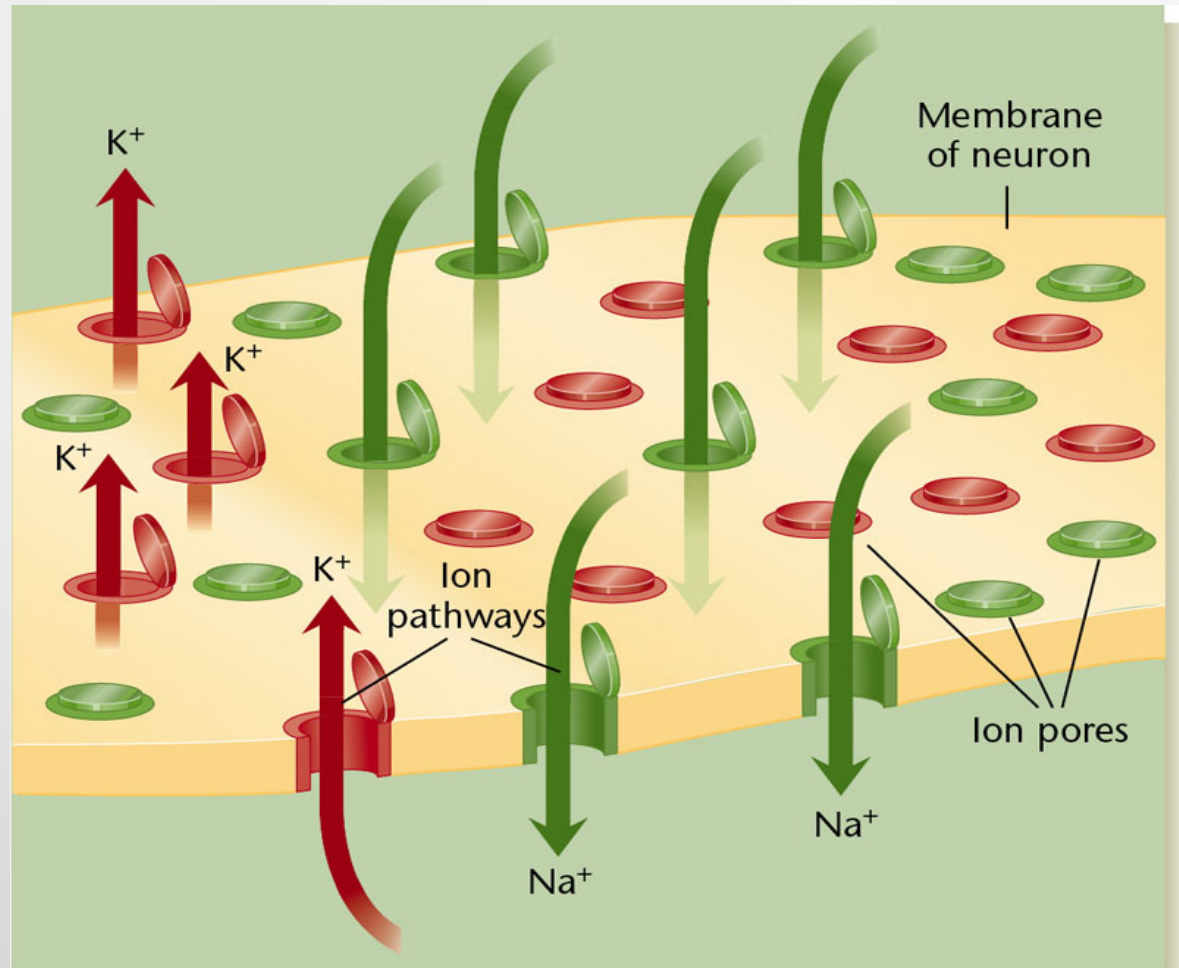
The Nerve Impulse

- The membrane is **selectively permeable**, allowing some chemicals to pass more freely than others.
- Sodium, potassium, calcium, and chloride pass through channels in the membrane.
- When the membrane is at rest:
 - Sodium channels are closed.
 - Potassium channels are partially closed.

The Nerve Impulse

- The membrane is **selectively permeable**, allowing some chemicals to pass more freely than others.
- Sodium, potassium pass through channels in the membrane.
- When the membrane is at rest:
 - Sodium channels are closed.
 - Potassium channels are partially closed allowing the slow passage of sodium.

Selectively Permeable Membrane



Ionic Balance

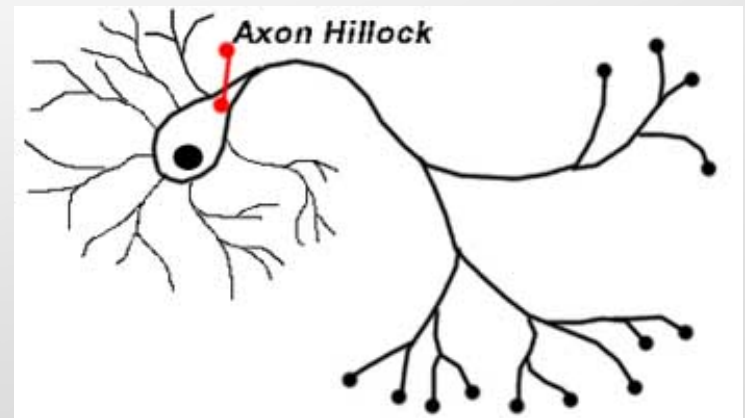
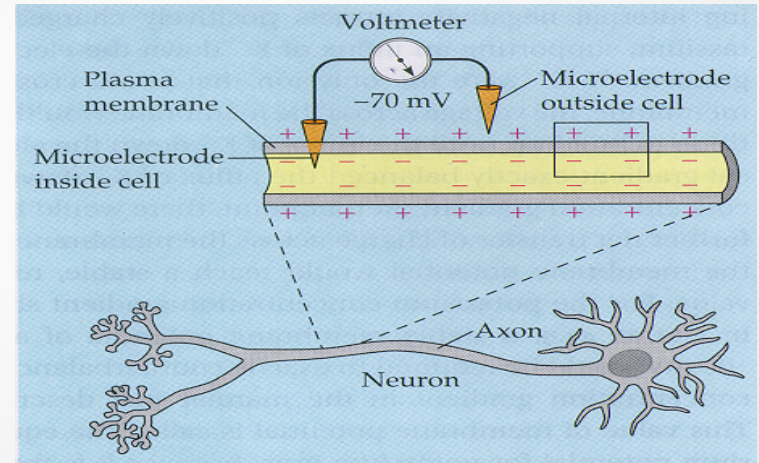
The membrane is acted on by three forces:

- **electrical gradient** -- which is the tendency for ions to move from areas of high charge to areas of low charge
- **concentration gradient** -- which is the tendency for ions to move from areas of high concentration to areas of low concentration.
- **sodium-potassium pump** -- a membrane mechanism which actively transports ions across the membrane. The sodium potassium pump pumps 3 Na^+ ions out of the cell and 2 K^+ ions into the cell on each cycle. Many of the K^+ ions leak back out due to the concentration gradient further increasing the negativity of the inside of the cell.

Resting Action potential

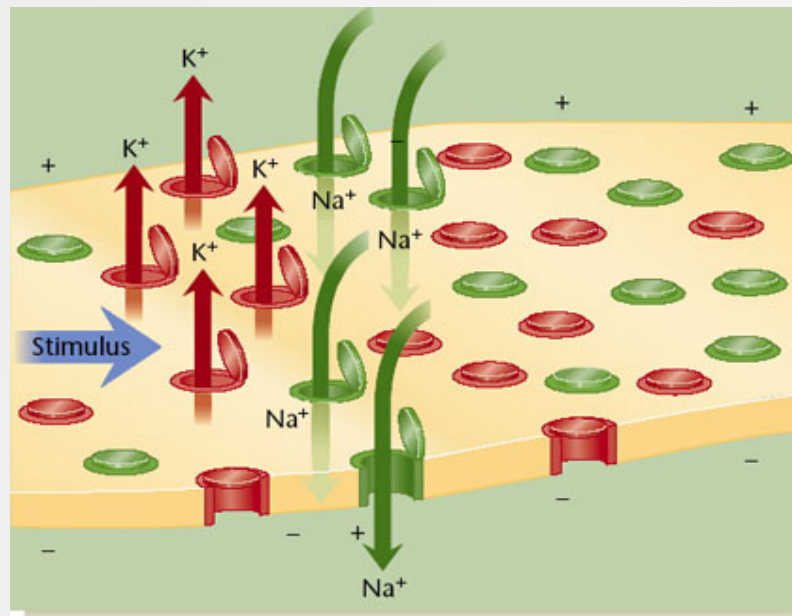
Both the inside and outside of the axon are made from positive ions. The negative voltage reading occurs as the inside has less positive ions than the outside. It is there less positive.

i.e. at rest sodium (Na^+) is outside the plasma membrane and potassium (K^+) inside.

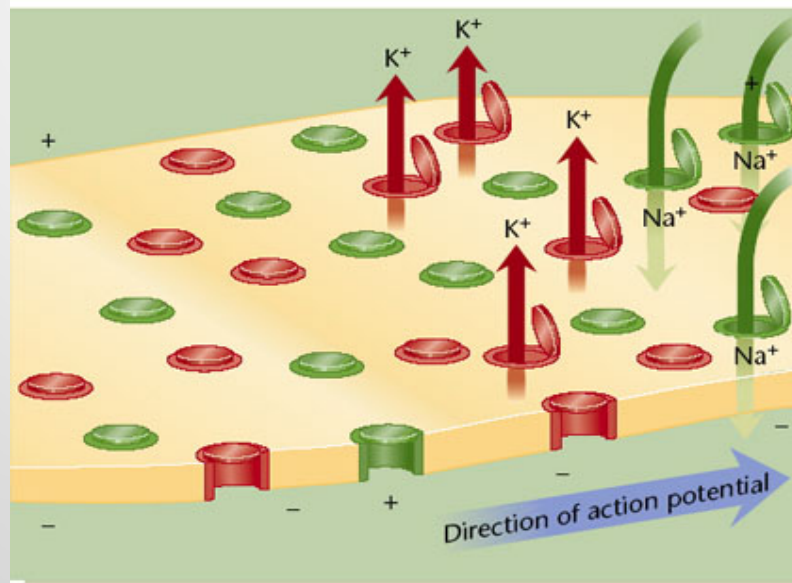


Propagation of the impulse

- When the voltage activated channels in the axon hillock open up and allow sodium ions in, a chain reaction is started.
- The sodium ions spread down the axon and cause the voltage activated channels further down the axon to open up.
- This lets sodium ions into that part of the axon and the reaction spreads down the axon.
- Sodium gates close and Potassium gates open causing the flow of potassium to outside the axon. Thereby returning the voltage to negative inside the axon
- The change in voltage on the inside of the cell which occurs when the sodium ions enter through the voltage activated channels is called the action potential or nerve impulse.
- This action potential obeys the all-or-none law, that is, once it starts you always get a full size action potential, that is just as big when it reaches the end of the axon as it was at the start.

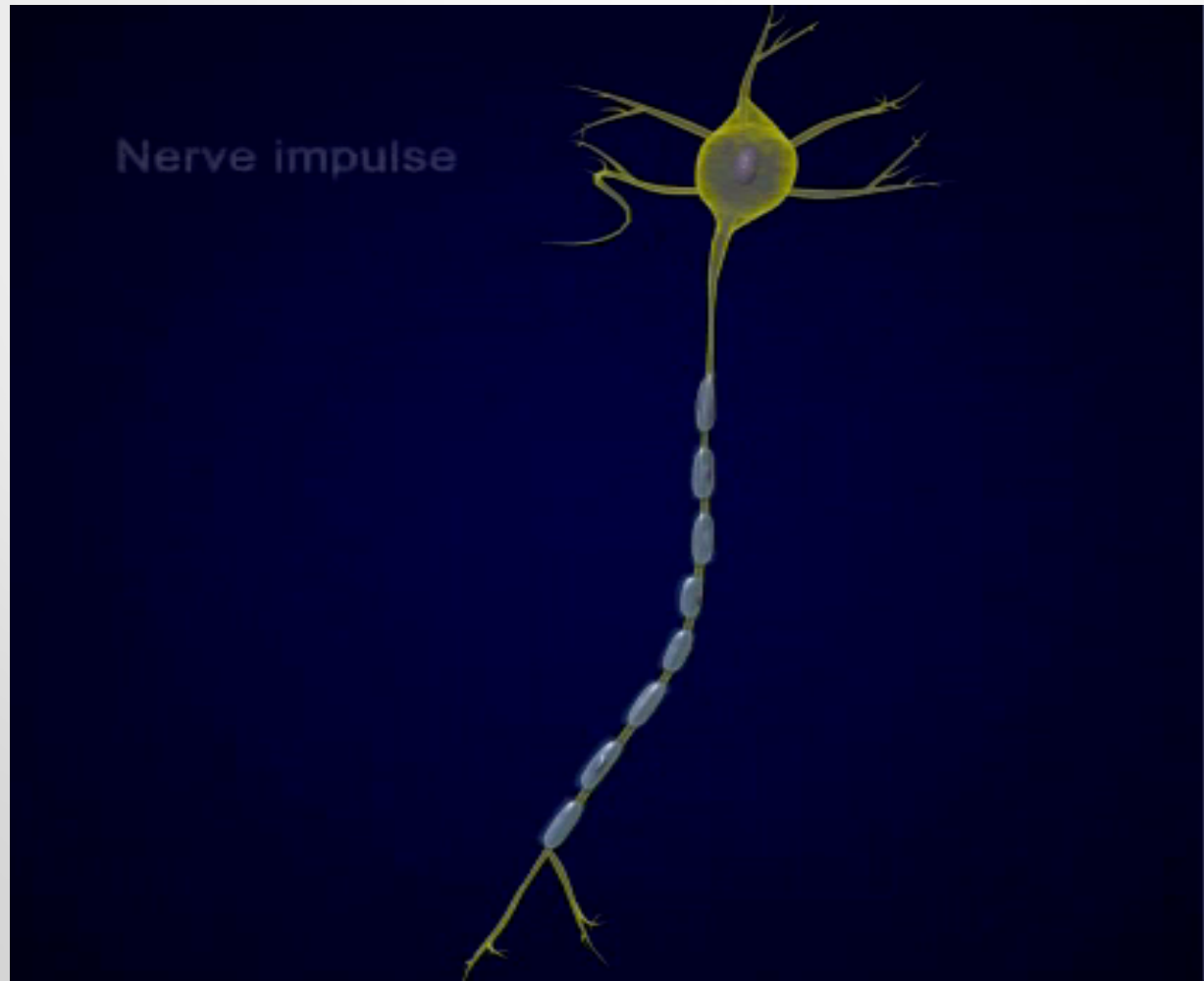


(a)



(b)

The Nerve Impulse – Action Potential



Recovery

- Once the signal has passed the sodium potassium pump exchanges sodium inside the axon from potassium outside until resting conditions are restored.

Nerve impulse transmission

- In the resting nerve, the voltage-gated channel for K^+ is partially open, creating a potential across the membrane that is negative on the inside compared to the outside.
- When a stimulus is received, the channel for Na^+ opens for a brief period of time. The strong flow of positive charges from outside to inside creates a rapid reversal of polarity (positive inside and negative outside).
- The sharp depolarization is immediately followed by the opening of K^+ channels and the closing of Na^+ channels. The rate of flow of K^+ is not as great as the rate of the preceding flow of Na^+ .
- The Na^+-K^+ pump restores the original electrical potential

REFRACTORY PERIOD

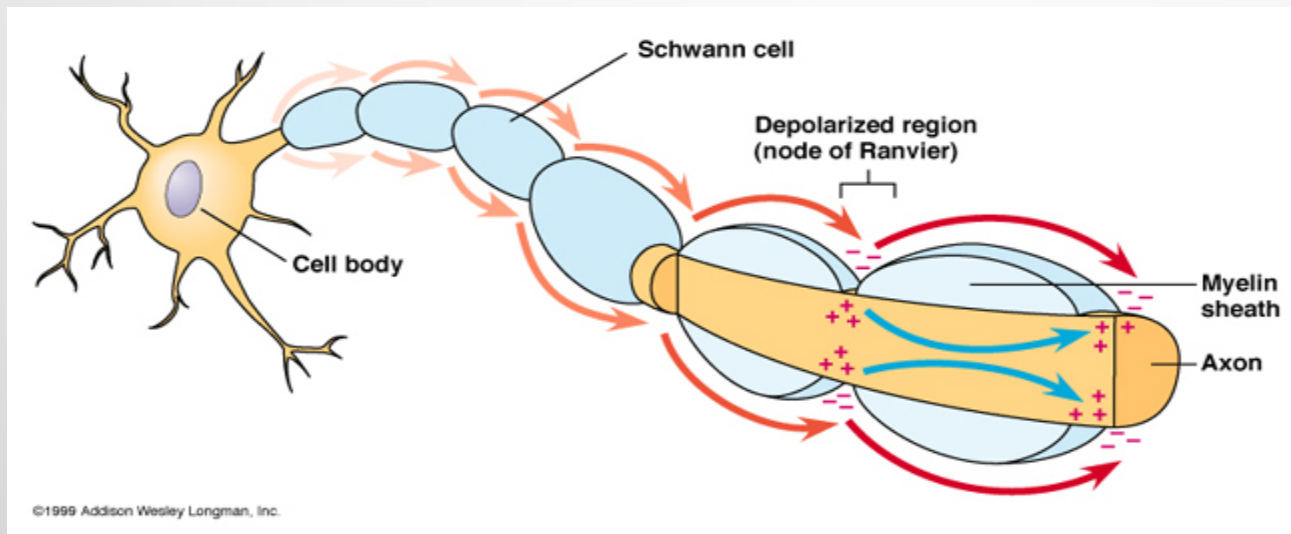
Sodium channels cannot be activated again for a short period after the passing of a nerve impulse. Thus a short period of time must pass before another impulse can be generated

larger diameter fibres recover faster and so can transmit up to 2500 impulses per second, while smaller diameter fibres have a longer refractory period and so may only transmit as few as 250 impulses per second

The Nerve Impulse

- The myelin sheath of axons are interrupted by short unmyelinated sections called **nodes of Ranvier**.
- At each node of Ranvier, the action potential is regenerated by a chain of positively charged ion pushed along by the previous segment.

Myelinated Axon



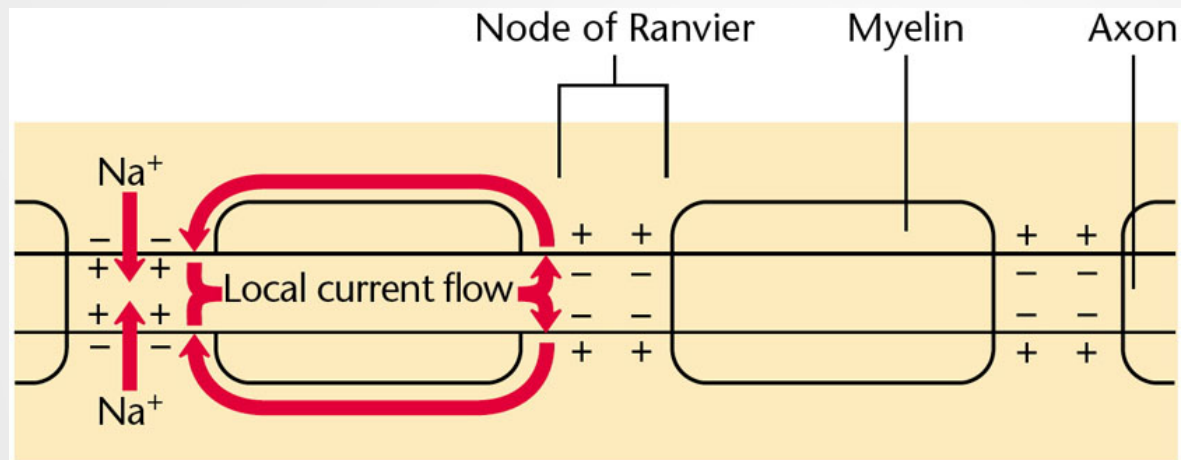
SALTATORIAL CONDUCTION

Saltatory conduction is the word used to describe this “jumping” of the action potential from node to node.

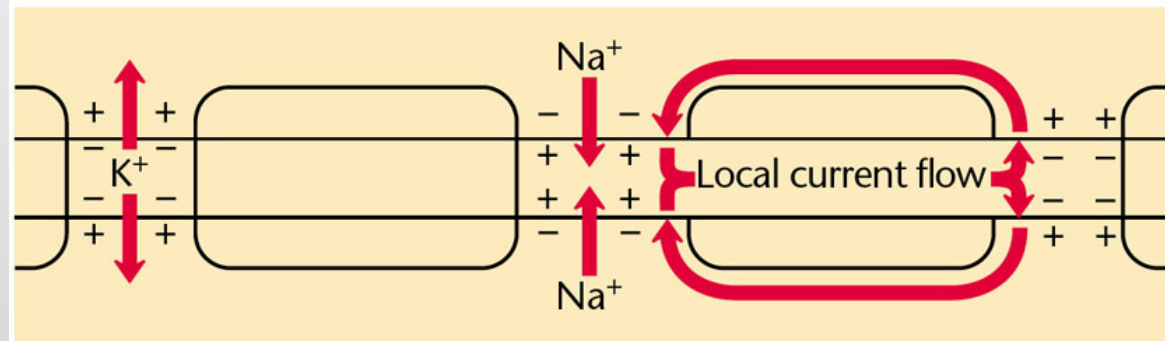
- Provides rapid conduction of impulses
- Conserves energy for the cell

Spaces between Schwann cells on myelinated axons are called Nodes of Ranvier. These gaps are vital for proper conduction of the impulse along the PNS. The sheath contains lipoproteins which does not conduct and electric current so membrane depolarisation can not occur where it is surrounded by the sheath. The depolarisation occurs in the space (node) and will jump to the next node creating a much faster impulse and requiring less energy because less action required by Na^+/K^+ pump

SALTATORIAL CONDUCTION



(a)



(b)

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SPEED OF NERVE IMPULSE

Impulses can travel up to 130 m/second in large (diameter) fibres i.e. all motor nerves leading to skeletal muscle and large sensory neurons associated with touch, pressure, heat, cold and position of joints. Other fibres which stimulate smooth muscle and glands have a smaller diameters and transmit about 10 m/sec. Some other smaller fibres are as slow as 0.5m/s

The Nerve Impulse Local neurons

Not all neurons have lengthy axons.

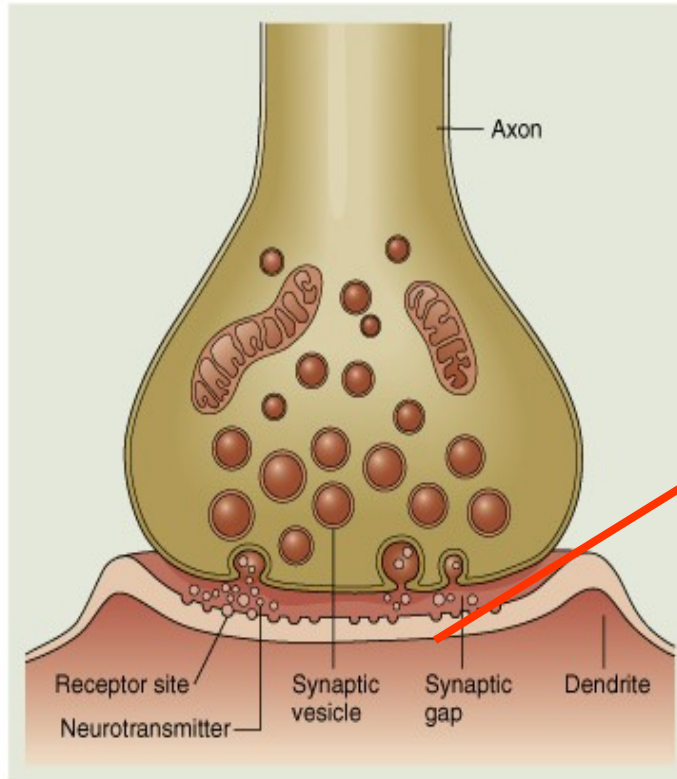
- **Local neurons** have short axons, exchange information with only close neighbors, and do not produce action potentials.
- When stimulated, local neurons produce **graded potentials** which are membrane potentials that vary in magnitude and do not follow the all-or-none law,.
- A local neurons depolarizes or hyperpolarizes in proportion to the stimulation.

Synaptic Transmission

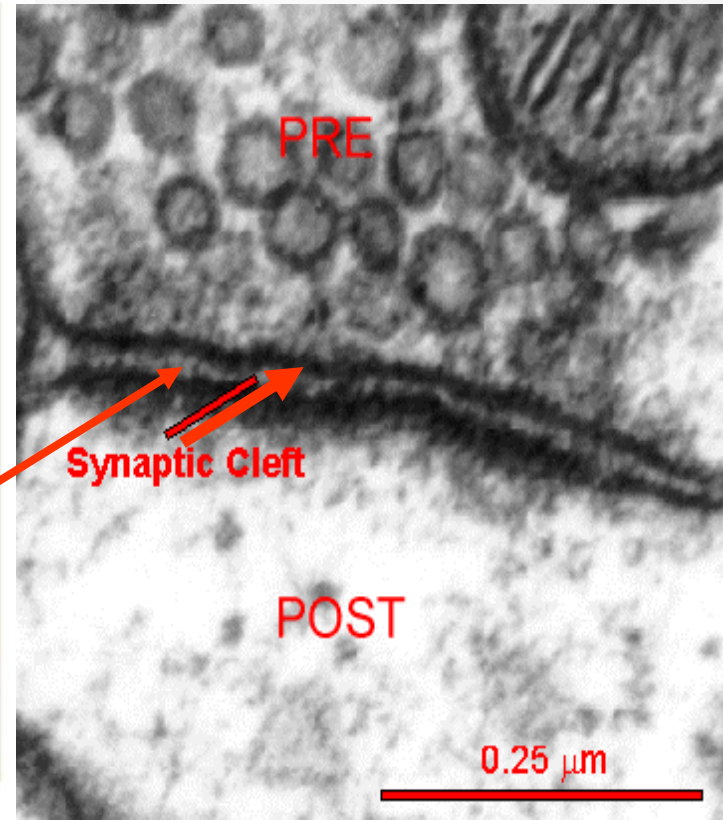
Once the impulse reaches the end of the nerve it must pass to another nerve or the effector site e.g. muscle fibre.

This occurs through the secretion of neurotransmitters such as acetylcholine

Transmission between nerve fibres



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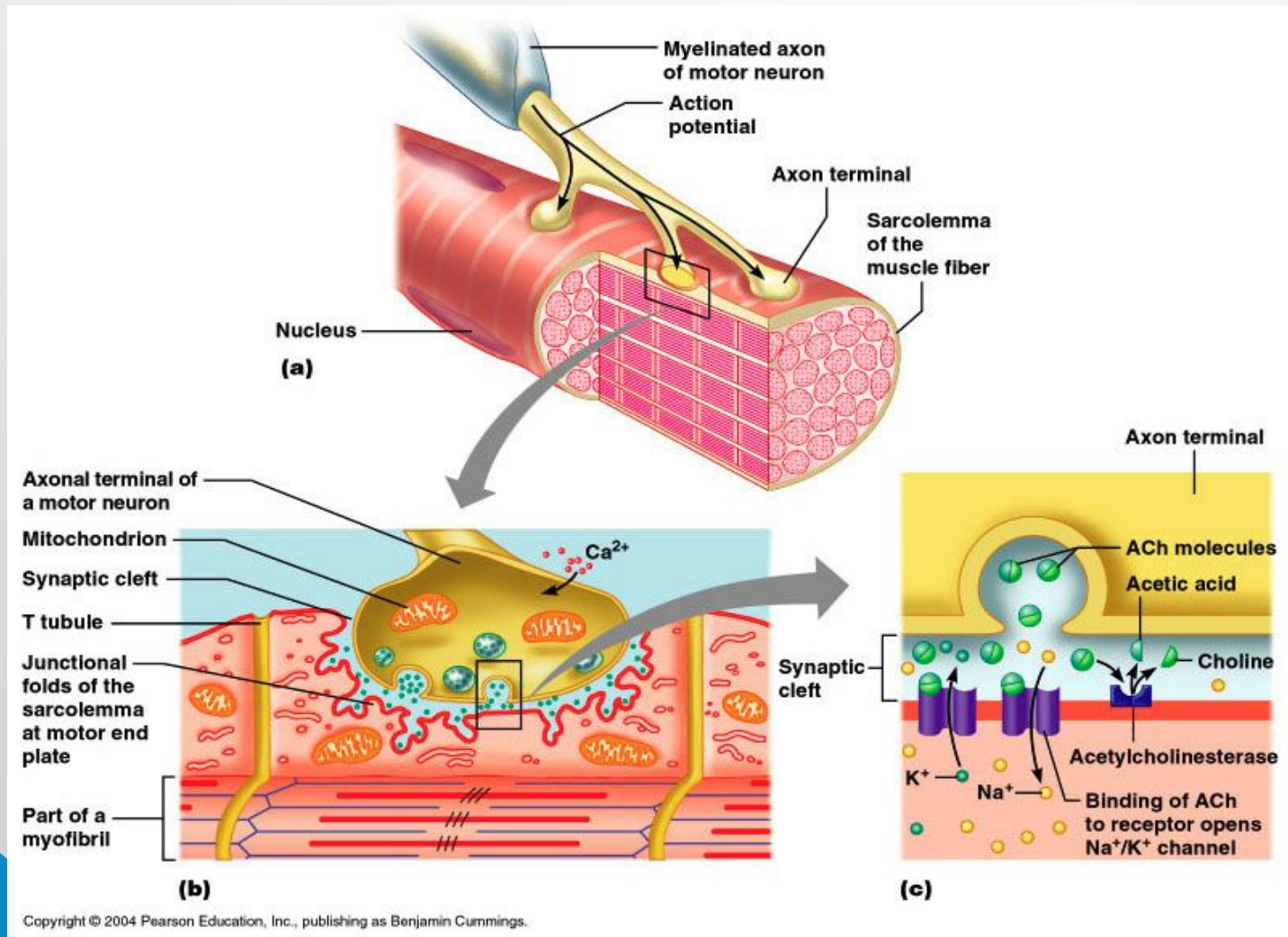
Synaptic transmission

- refers to the propagation of nerve impulses from one nerve cell to another
- This occurs at a specialized cellular structure known as the **synapse** - a **junction at which the axon of the pre-synaptic neuron terminates at some location upon the postsynaptic neuron**
- Nerve impulses are transmitted at synapses by the release of chemicals called **neurotransmitters**

Synaptic transmission

- When the action potential reaches the terminal region of the pre-synaptic membrane, voltage gated calcium channels open and calcium diffuses down into the pre-synaptic nerve region.
- This increase in calcium concentration results in the migration of acetylcholine containing vesicles to the pre-synaptic membrane.
- The acetylcholine is then released via the process of exocytosis into the synaptic cleft and binds to specialised acetylcholine receptors.
- This opens sodium channels in the postsynaptic membrane allowing sodium to flow into the synaptic cleft. If enough sodium is transferred from into region then the polarity in the receptor region changes and an impulse is generated.

Transmission of Nerve impulse across to a muscle fibre



Task

- Find this article **Physiological and Neural Adaptations to Eccentric Exercise: Mechanisms and Considerations for Training**
- Read it and discuss your thoughts on the information contained within it.
- What are the neural responses to training?
- Post your thoughts on the forum by the start of next week.