# ANIMAL FORM AND FUNCTION

## Communication I: Nervous and Sensory System

The two forms communication in an animal that integrate body functions to maintain homeostasis are

| Neurons | Hormones |
| --- | --- |
| Which transmit electrical signals that report information or initiate a quick response in a specific tissue. | Which are slower, chemical signals that initiate a widespread, prolonged response, often in a variety of tissue |

## NEURONS: THE BASIC FUNCTIONAL UNITS OF THE NERVOUS SYSTEM

- **Neuron** (Gr. ‘nerve”) is the functional unit of the nervous system.
- Neurons are specialized to produce signals that can be communicated from one part of an animal’s body to another.
- Neurons have two important properties:

1. Excitability (the ability to respond to stimuli)
2. Conductivity (the ability to conduct a signal)

- The three functional types of neurons:

1. Sensory (receptor or afferent) neurons
2. Interneurons (association) neurons
3. Motor (effector or efferent) neurons

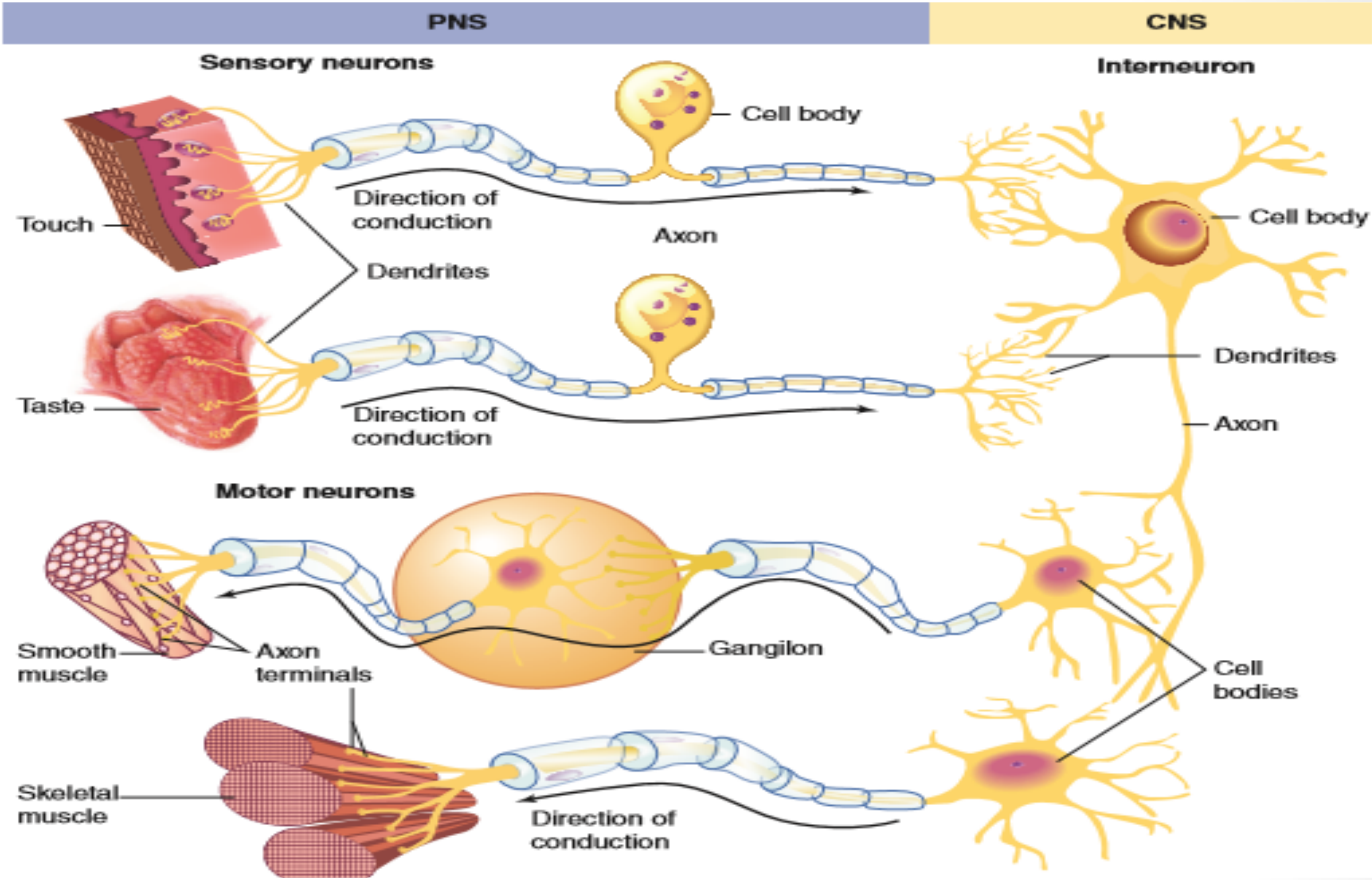



**Fig: Types of Vertebrate Neurons. The brain and spinal cord make up the central nervous system (CNS) of vertebrates, and sensory and motor neurons form the peripheral nervous system (PNS). The sensory neurons of the peripheral nervous system carry information about the environment to the CNS. Within the CNS, interneurons provide the links between sensory and motor neurons. Motor neurons of the PNS carry impulses or "commands" to the muscles and glands (effectors) of a vertebrate.**

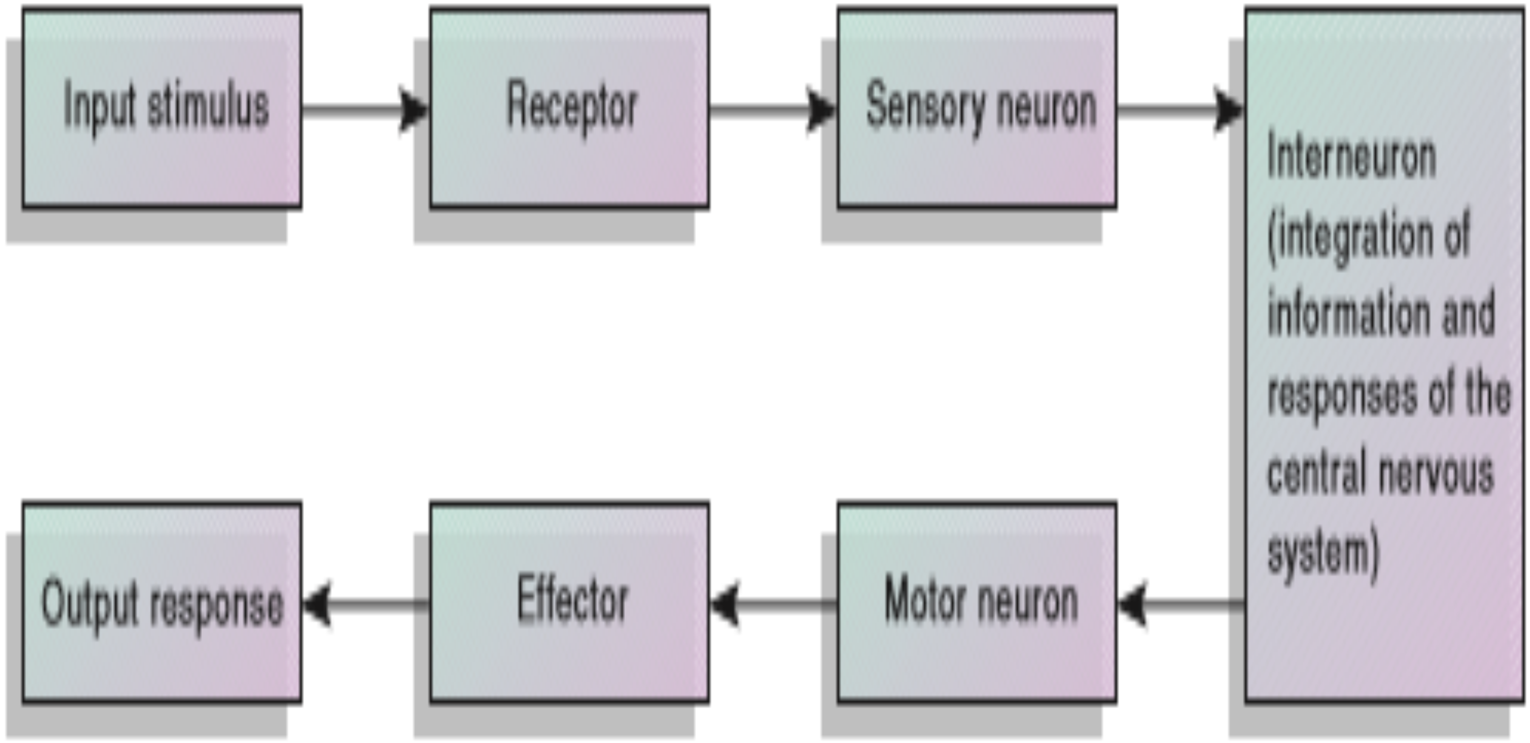



**Fig: Generalized Pathway for the Flow of Information within the Nervous System**

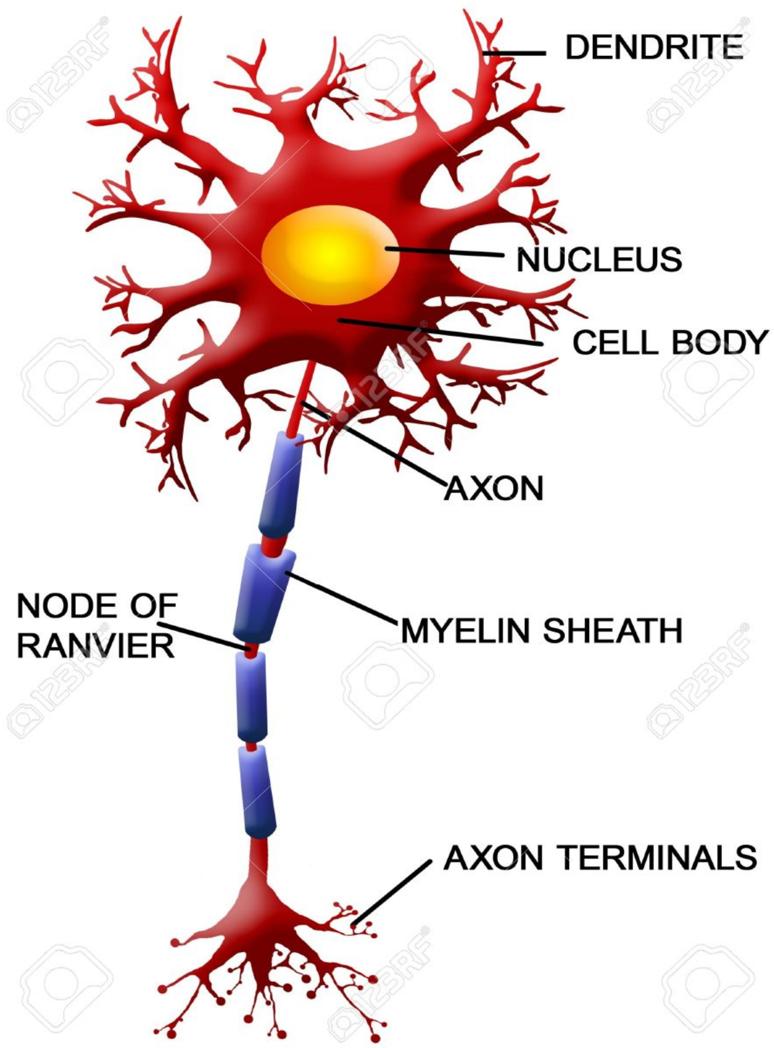
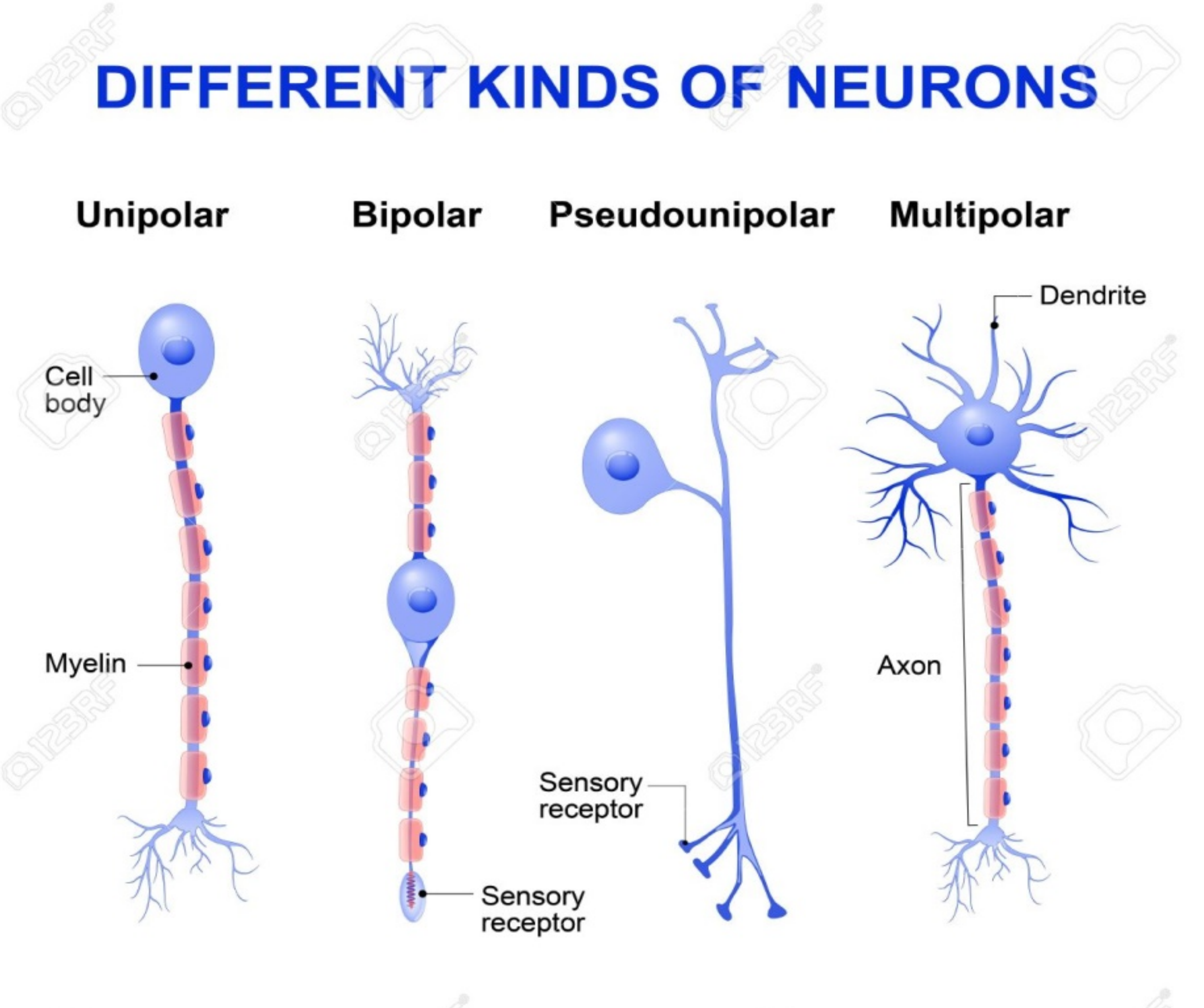



Fig: A Neuron Structure

## Neurons structure

- **Cell Body --**Enlarged part containing nucleus
- **Dendrites** -- Short, cytoplasmic extensions that receive stimuli
- **Axon** -- Single, long extension that conducts impulses away from cell body


DIFFERENT KINDS OF NEURONS
Unipolar
Bipolar
Pseudounipolar
Multipolar
Cell body
Myelin
Sensory receptor
Sensory receptor
Dendrite
Axon

## Neuron communication

The language (signal) of a neuron is the nerve impulse or action potential.

## Resting Membrane Potential

- Non conducting
- More negative charges on the inner side of the neuron as compared to the outer side.
- The difference in electrical charge between the inside and the outside of the membrane at any given point is due to the relative numbers of positive and negative ions in the fluids on either side of the membrane, and to the permeability of the plasma membrane to these ions.

# Resting Membrane Potential

- The resting potential is measured in millivolts (mV)
- A millivolt is 1/1000 of a volt
- Normally, the resting membrane potential is about -70 mV, due to the unequal distribution of various electrically charged ions.
- Sodium (($Na^+$) ions are more highly concentrated in the fluid outside the plasma membrane, and potassium ($K^+$) and negative protein ions are more highly concentrated inside

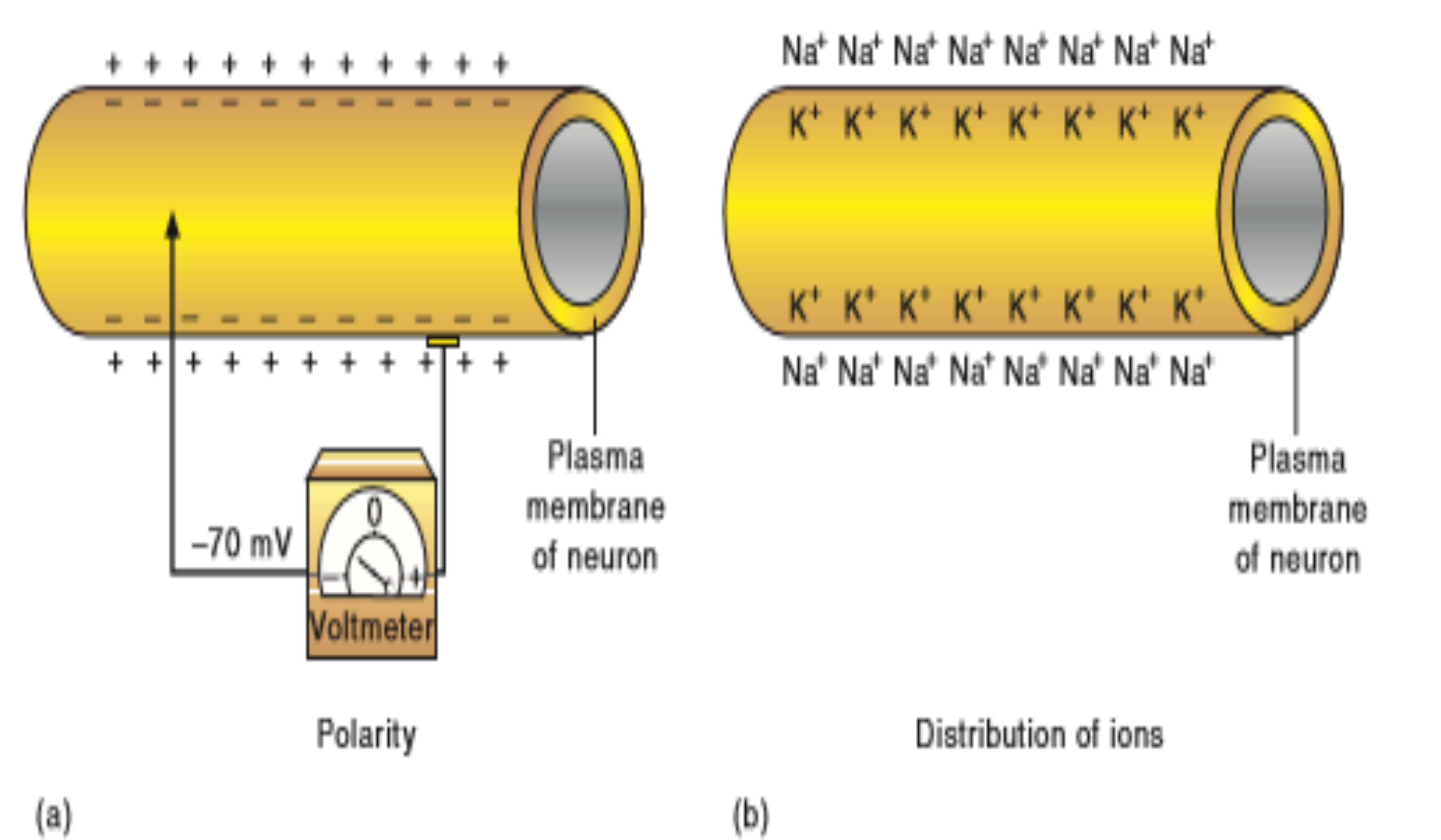



**Fig: Resting Membrane Potential. (a) A voltmeter measures the difference in electrical potential between two electrodes. When one microelectrode is placed inside a neuron at rest, and one is placed outside, the electrical potential inside the cell is 270 mV relative to the outside. (b) In a neuron at rest, sodium is more concentrated outside the cell and potassium is more concentrated inside the cell. A neuron in this resting condition is said to be polarized.**

# Sodium-Potassium Pump

- These mechanisms maintain a balance between the sodium ions and potassium ions on both sides of the membrane and create a membrane potential.
- Some channels are always open, but others open or close by the position of gates, which are proteins that change shape to block or clear the channel.
- Whether a gate opens or closes a channel depends on the membrane potential. Such gates are said to be voltage regulated.
- Some of these membrane channels are specific for sodium ions, and others are specific for potassium ions.

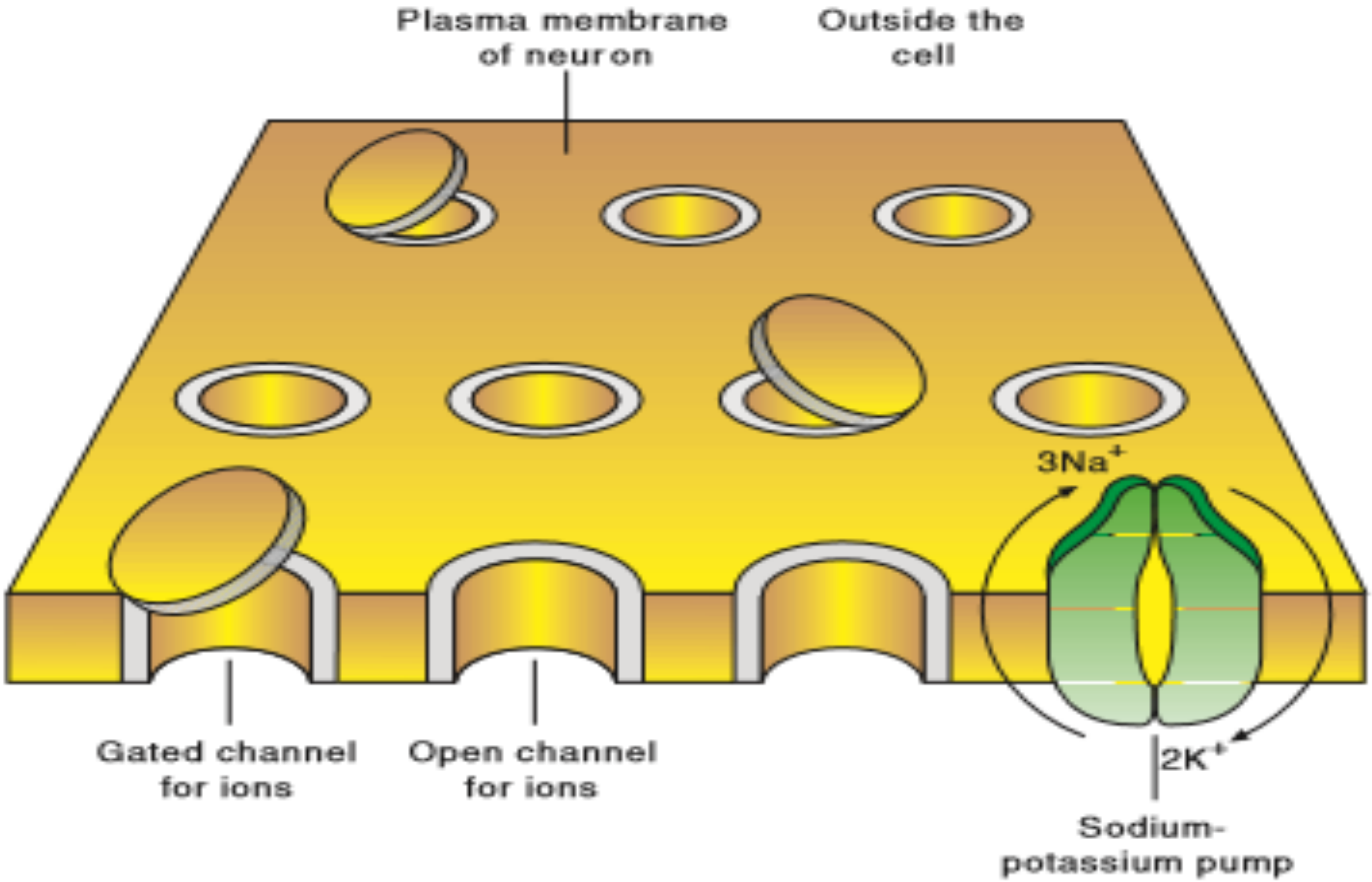



**Fig: Ion Channels and the Sodium-Potassium Pump.**

# Graded Potentials

- Graded potentials are changes in the membrane potential that are confined to a relatively small region of the plasma membrane.
- They are called graded potentials because the magnitude of the potential can vary ("is graded").
- They are usually produced by some specific change in the cell's environment acting on a specialized region of the membrane.

# Mechanism of Neuron Action: Changing the Resting Membrane Potential into the Action Potential (Nerve Impulse)

- A stimulus that is strong enough to initiate an impulse is called a **threshold stimulus**.
- A minimum stimulus (threshold) is necessary to initiate an action potential, but an increase in stimulus intensity does not increase the strength of the action potential. The principle that states that an axon will ‘fire’ at full power or not at all is the **all-or-none law.**
- When such a stimulus is applied to a point along the resting plasma membrane, the permeability to $Na^+$ ions increase at that point.
- The inflow of positively charged $Na^+$ ions causes the membrane potential to go from -70 mV toward 0.
- This loss in membrane polarity is call **Depolarization.**

- When depolarization reaches a certain level, special $Na^+$ channels (voltage-gated) that are sensitive to changes in membrane potential quickly open, and more $Na^+$ ions rush to the inside of the neuron.
- Shortly after the $Na^+$ ions move into the cell, the $Na^+$ gates close, but now voltage gated $K^+$ channels open, and $K^+$ ions rapidly diffuse outward.
- The movement of the $K^+$ ions out of the cell builds up the positive charge outside the cell again, and the membrane becomes **repolarized**.
- This series of membrane changes triggers a similar cycle in an adjacent region of the membrane, and the wave of depolarization moves down the axon as an **action potential**.

- After each action potential, there is an interval of time when it is more difficult for another action potential to occur because the membrane has become hyperpolarized (more negative than 270 mV) due to the large number of $K^+$ ions that rushed out.
- This brief period is called the **refractory period or hyperpolarization.**
- During this period, the resting potential is being restored at the part of the membrane where the impulse has just passed.
- Afterward, the neuron is repolarized and ready to transmit another impulse.

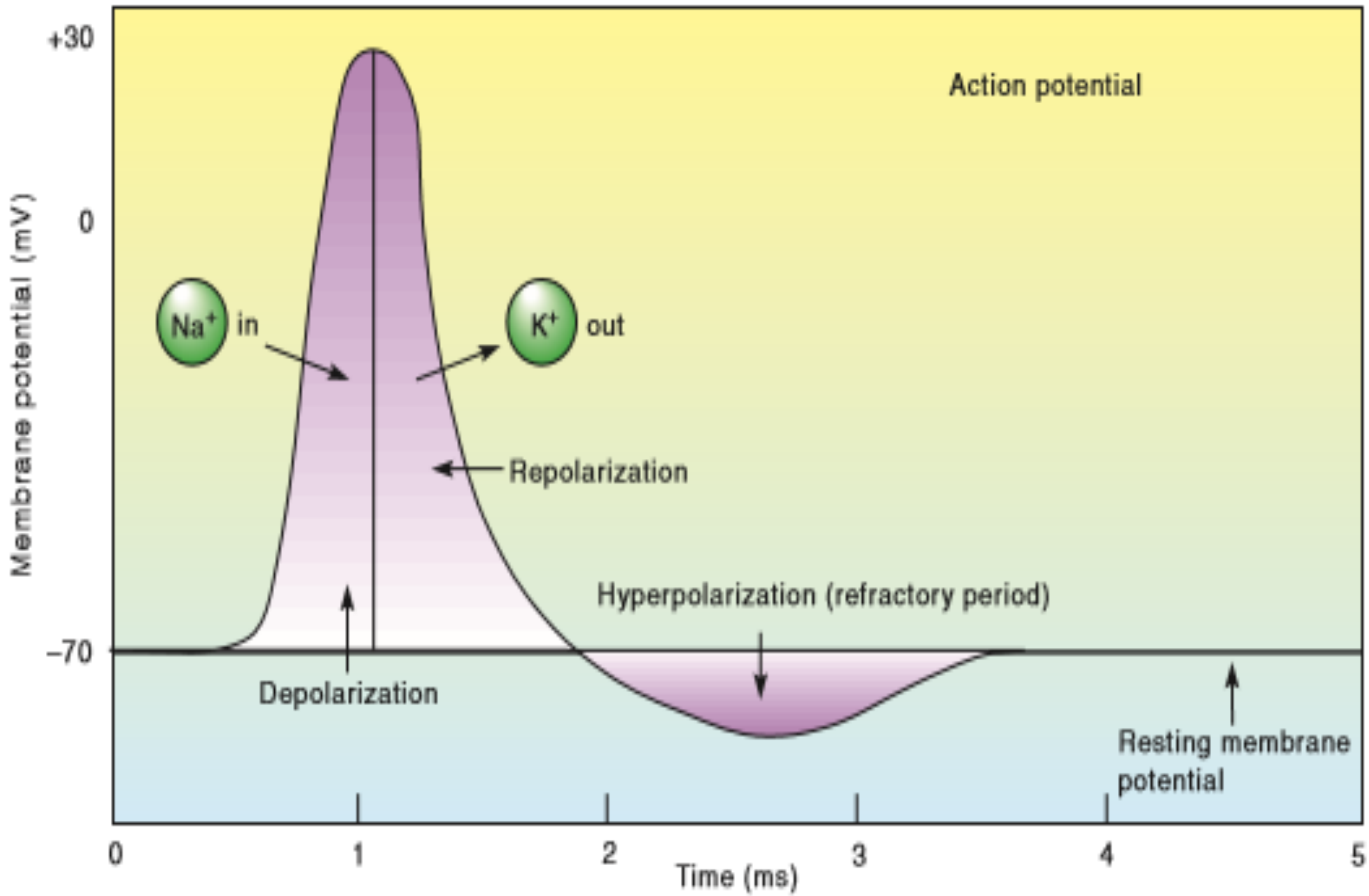
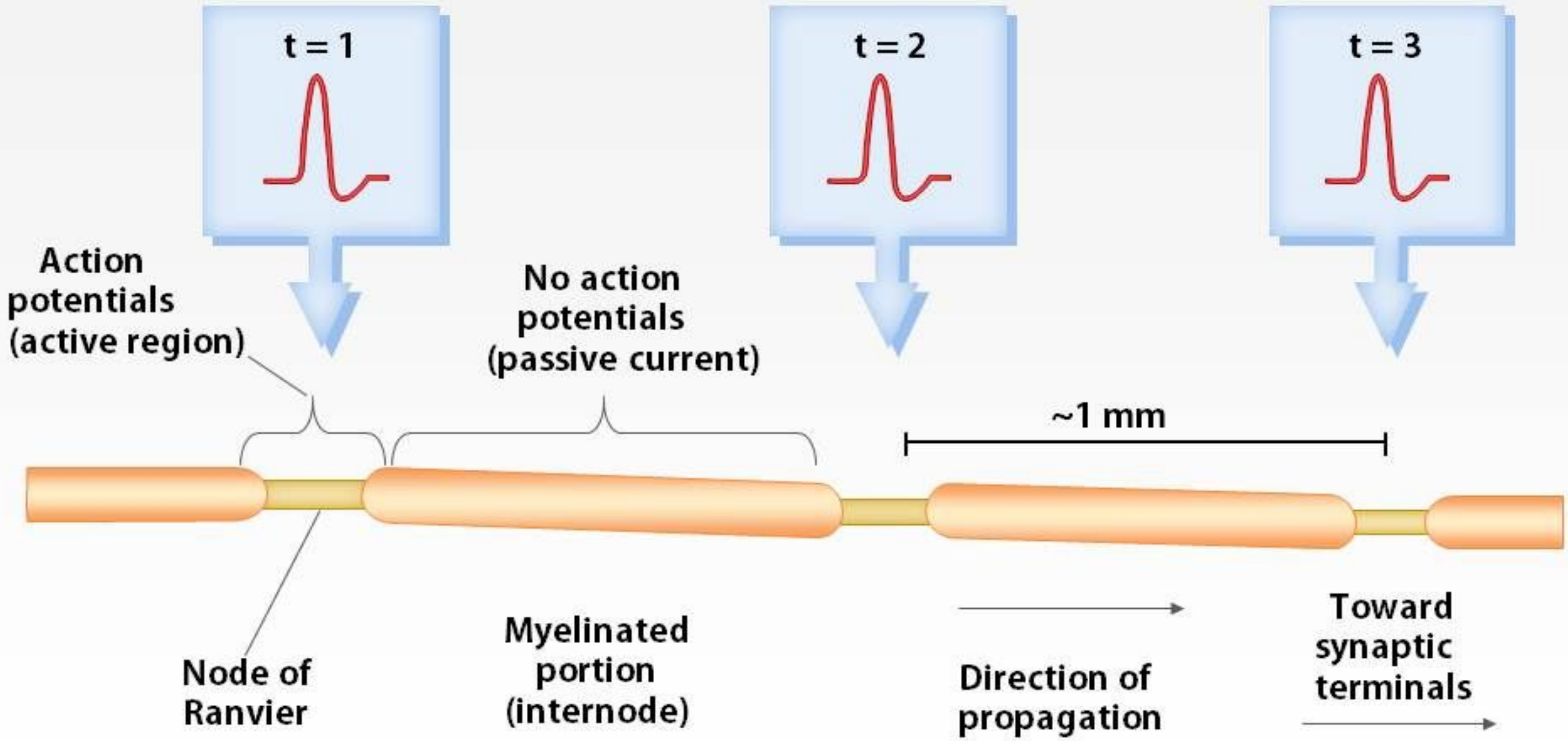



**Fig: An Action Potential Recording. During the depolarization phase of the action potential, sodium ($Na^+$) ions rush to the inside of a neuron. The repolarization phase is characterized by a rapid increase in potassium ($K^+$) ions on the outside of the neuron. The action potential is sometimes called a "spike" because of its shape on a computer screen.**

# Saltatory Conduction

- Saltatory conduction  (L. *saltare*, to jump) is the propagation of action potential between the nodes of ranvier in myelinated axons.
- Saltatory conduction is more energy efficient and leaps longer intervals distances.
- Action potential is generated only at the neurofibrils

# Saltatory Conduction



## ❑ TRANSMISSION OF THE ACTION POTENTIAL BETWEEN CELLS:

- After an action potential travels along an axon, it reaches the end of a branching axon terminal called the end bulb.

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- The synapse is the junction between the axon of one neuron and the dendrite of another neuron or effector cell.

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- The space (junction) between the end bulb and the dendrite of the next neuron is the synaptic cleft.

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- The neuron carrying the action potential toward a synapse is the presynaptic ("before the synapse") neuron

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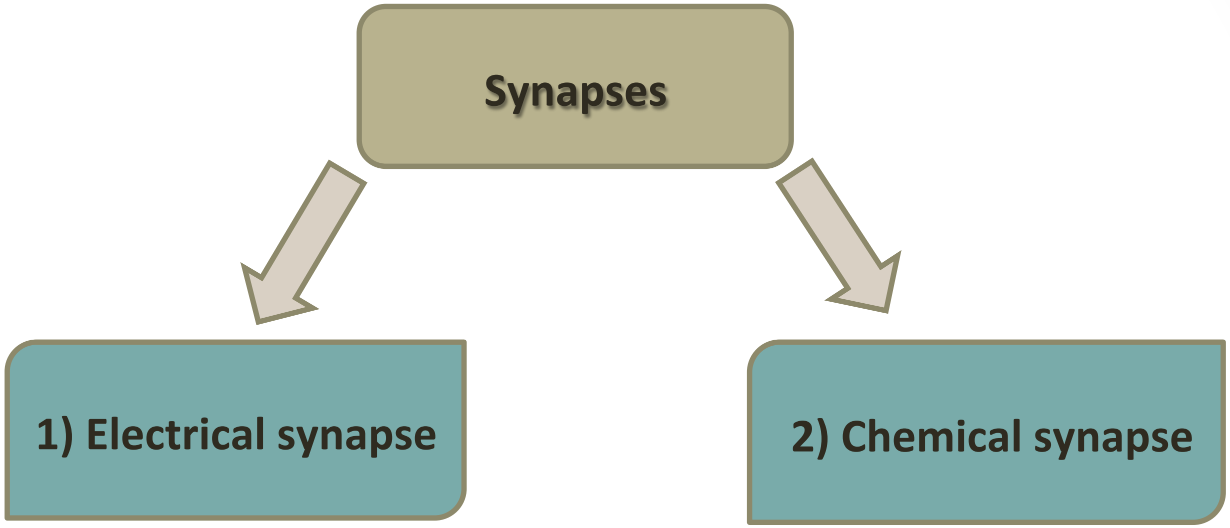
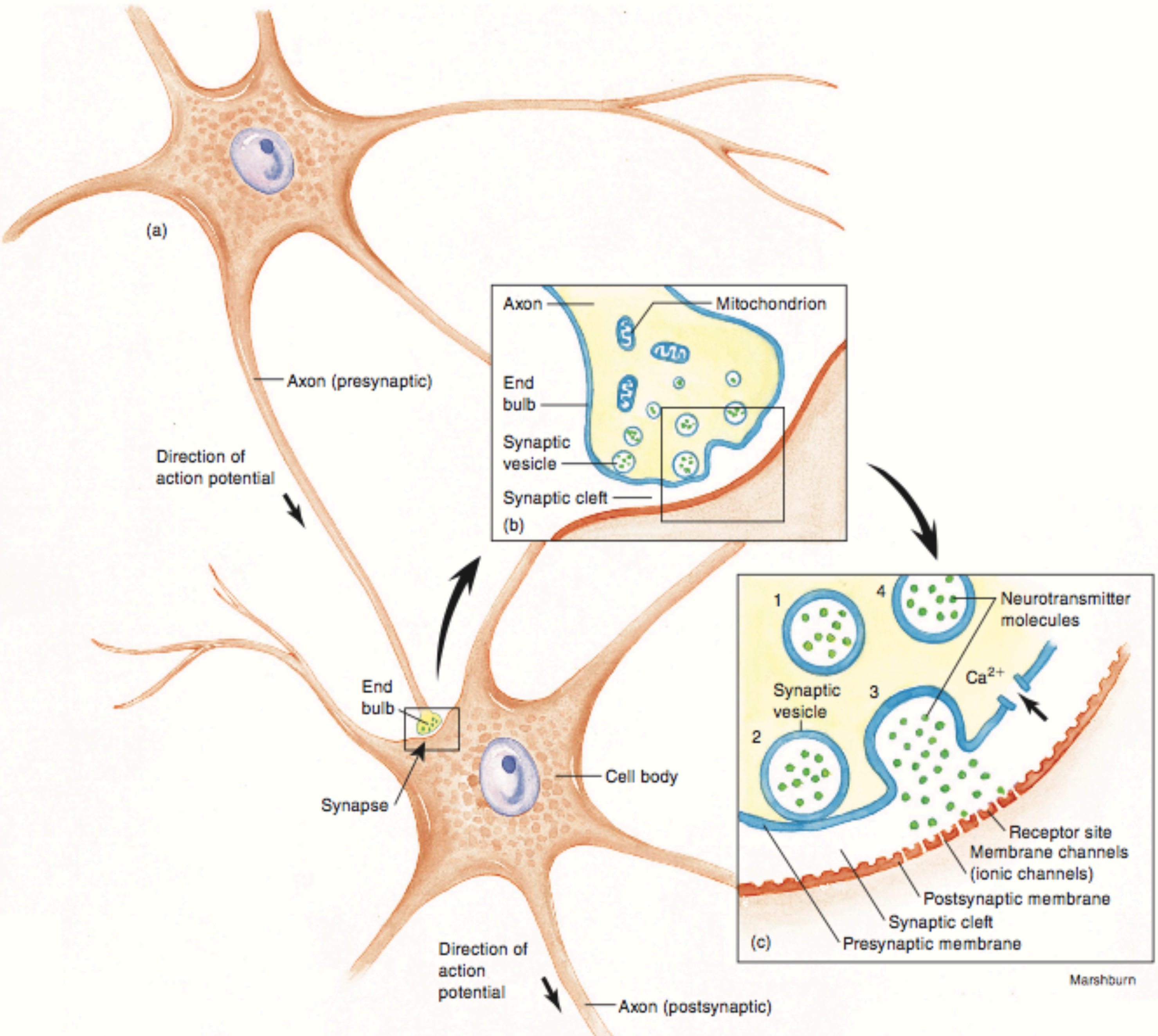
- It initiates a response in the receptive segment of a postsynaptic ("after the synapse") neuron leading away from the synapse




## 1) Electrical synapse

- ✓ Nerve impulses transmit directly from neuron to neuron when positively charged ions move from one neuron to the next.
- ✓ These ions depolarize the **postsynaptic membrane**.
- ✓ An electrical synapse can rapidly transmit impulses in both directions.
- ✓ Electrical synapses are common in fishes and partially account for their ability to dart swiftly away from a threatening predator.


(a)
Axon (presynaptic)
Direction of action potential
End bulb
Synapse
Cell body
Direction of action potential
Axon (postsynaptic)
Axon
Mitochondrion
End bulb
Synaptic vesicle
Synaptic cleft
(b)
1
2
3
4
Neurotransmitter molecules
Synaptic vesicle
Ca2+
Receptor site
Membrane channels (ionic channels)
Postsynaptic membrane
Synaptic cleft
Presynaptic membrane
(c)
Marshburn

## 2) Chemical synapse

- two cells communicate by means of a chemical agent called a neurotransmitter, which the presynaptic neuron releases.

↓

- A neurotransmitter changes the resting potential in the plasma membrane of the receptive segment of the postsynaptic cell. creating an action potential in that cell, which continues the transmission of the impulse.

↓

- When a nerve impulse reaches an end bulb, it causes storage vesicles (containing the chemical neurotransmitter) to fuse with the plasma membrane.

↓

- The vesicles release the neurotransmitter by exocytosis into the synaptic cleft.

↓

- Neurotransmitter binds with receptor protein sites in the postsynaptic membrane, it causes a depolarization similar to that of the presynaptic cell.

- The impulse continues its path to an eventual effector.

↓

- Once acetylcholine has crossed the synaptic cleft, the enzyme acetylcholinesterase quickly inactivates it