The Neuron

27 Slides

The neuron is the structural and functional unit of the nervous system.
- A cell highly specialized for the 
  - Generation 
  - Conduction 
  - Of an electrical impulse 

There are at least four major functions carried out by the neurons through its different parts.
- 1) It receives input from other neurons 
  - Chiefly by way of its dendrites 
  - And soma.

2) It makes computations:
  - Particularly summation of:
    - Inhibitory postsynaptic potentials (IPSP)
    - Excitatory postsynaptic potentials (EPSP)
  - Eventually leading to the generation of an action potential
  - Through depolarization of the membrane in the region of the axon hillocks
  - Each neuron has on the average 10,000 neurons communicating with it.

3) Conducts the action potential along the axon to the axon terminals. (Terminal buttons, buttons, synaptic knobs)

4) Transfers information by synaptic transmission at the terminals:
  - To other neurons
  - Muscle cells
  - Or gland cells

The neuron is a highly specialized cell to handle information,
- Whether initiated in the:
  - External environment
  - Internal environment
  - Or the central nervous system (CNS)

Once stimulated the nerve cell generates and conducts a neural impulse along its fibers.
- The transmission of these electro-chemical impulses is an active biological process
- Unlike the passive conduction of an electrical current along a wire.
- Nerve impulses are transient changes in the physico-chemical state of the cell membrane.
- An impulse, once initiated in an elongated excitable cell, propagates automatically, without further dependence on the initiating stimulus, over the entire cell membrane.
- Accompanying the transient alterations underlying the impulse is a readily detectable electrical change, called the:
  - Action potential.
This action potential occur because of the exchange of ions. Between the inside of the neuron and the outside of the neuron. The sequence of ionic fluxes:
- As soon as the threshold of excitation is reached
- The membrane barrier to sodium (Na+) drops and Na+ comes rushing in.
- The membrane once again becomes resistant to the flow of Na+
- The whole process of sodium influx last only about one millisecond.
- The membrane now drops its resistance to potassium (K+).
- Since the inside of the axon is now positively charged
- K+ ions are driven out of the cell.

Finally, the K+ resistance of the membrane goes back up to its normal level
- The sodium-potassium pump removes the Na+ ions that leaked in
- And retrieves the K+ ions that leaked out
- And homeostasis occurs.

Components of neural transmission:
- The All or None Principle
- The Principle of One-Way Conduction
- Absolute refractory period (1.0 millisecond)
- Relative refractory period (2.0 - 4.0 millisecond)

Neural Transmission (continued)
- Action potentials transmitted over chains of neurons are the coded language
- in which changes in the environment are signaled to the brain
- To make us aware of what is happening in the external world.
- Natural stimuli that produce action potentials and elicit both conscious awareness and behavioral responses are:
  - Light
  - Mechanical deformation
  - Thermal changes
  - And chemical changes

Sensory Receptors
- All sensory receptors subserve a common functions:
  - The transformation of physical energy into electrical potential change.
  - Transduction is the process by which one form of energy is changed to another form of energy.
- All receptors are specialized to respond to one type of sensory input:
  - It is wrong to suppose that they are unable to respond to more than one kind of stimulation.
  - If we stimulate a visual receptor with light, pressure, or electrical current, we get only a visual response.
  - This is because the sensory impression depends on where the sensory receptors is wired into the brain.

Sensory receptors (continued)
- Types of receptors:
  - Auditory receptors (ears) respond to mechanical deformation.
  - Photoreceptors (eyes) respond to light.
  - Tactile receptors (skin) respond to mechanical deformation.
  - Olfactory receptors (nose) respond to chemicals.
  - Gustatory receptors (mouth) respond to chemicals.
  - Pain receptors respond to mechanical deformation, chemical changes, and thermal changes.
  - Temperature receptors respond to thermal changes.
  - Body positions receptors respond to mechanical deformation.
  - Blood pressure receptors respond to mechanical deformation.
  - Blood chemistry receptors respond to chemicals

Sensory receptors (continued)
- The concept that one will perceive a sensation of the same nature no matter how a given receptor is stimulated is called the Doctrine of Specific Nerve Energies.
Synapses are used by the nervous system to process electrical signals as they travel from the receptor to the brain. The electrical signals generated in the receptors are processed by:
- The network of nerve fibers,
- Or neural circuits, through which the signals travel.

Neural Circuits

- Linear circuit, which requires 14 neurons.
  - Increase in the number of receptors stimulated
  - Increases the number of neurons firing

Neural Circuits (continued)

Three Examples of typical neural circuitry:

- A circuit with convergence, which requires 10 neurons.
  - Increase in the number of receptors stimulated
  - Increases the firing rate of neuron I.

- A circuit with convergence and inhibition.
  - Stimulate receptors C, D, & E increases the firing rate of neuron I.

Neural Circuits (continued)

Three Examples of typical neural circuitry:

- One of the first steps in the process of perception is transduction.
  - The transformation by the receptors of environmental energy into action potentials.

- Another step in the process of perception is another transformation:
  - The shaping of these action potentials so that they more efficiently transmit information about the stimulus.

- Let us examine an actual receptive field that response to concentric circles in the eye.
  - A receptive field that has been study in great detail is:
    - On center/Off surround
    - Off center/On surround
  - On center/Off surround the center is excitatory and the surround inhibitory.
A receptive field is the region of the receptor which, when stimulated, influences the firing rate of the neuron.

To understand the receptive field of On center/Off surround, we first must understand the morphology of the retina.

The retina is comprised of five layers of cells:
- The photoreceptors – rods and cones
- The bipolar cells
- The horizontal cells
- The amacrine cells
- The ganglion cells

The receptive field is called an On center/Off surround receptive field because it responds one way to stimulation of the center area and another way to stimulation of the area surrounding this center area.

The center–surround receptive fields are not limited to the visual system. We find similar fields for touch of the skin. It is not surprising that senses as different as vision and touch have similar receptive fields. Because although the experiences of seeing and feeling a touch are very different, both vision and touch have receptors that define surfaces on which we can locate stimuli.

The cerebral cortex is specialized for different sensory receptors.

Motor cortex & motor control of speech is located in the frontal lobes.

Somatosensory cortex is located in the parietal lobes.

Visual cortex is located in the occipital lobes.

Auditory cortex is located in the temporal lobes.

Cartoon of the homunculus constructed on the basis of such mapping. Note that the amount of somatosensory cortex devoted to the hands and face is much larger than the relative amount of the body surface.
Disproportional representation of various portions of the body musculature in the motor cortex
- Representations of parts of the body that exhibit fine motor control occupy a greater amount of space
  - Such as hands and face
- than those that exhibit less precise motor control.
  - Such as trunk

But what signals different qualities within a sense?
- It appears to be a cross between specificity and across-fiber-pattern.
  - That is, receptors appear to be most responsive to specific stimuli.
    - Specificity is equivalent to labeled lines
    - High frequencies stimulate the base end of the basilar membrane
  - But it appears that the brain is sensitive to patterns of activity across a large number of neurons.

Color vision is an example of coding for quality within a vision.
- Color vision depends on three receptors mechanism
  - Each with different spectral sensitivities
  - One that responds to long wave lengths red (700 nm)
  - Another that responds to medium wave lengths green (500 nm)
  - And a third that responds to short wave lengths blue (475 nm)
- According to the theory of color vision, light of a particular wavelength stimulates the three mechanisms to different degrees.
  - And the ratio of activity in the three mechanisms results in perception of a color.
  - Each color is, therefore, coded in the nervous system by its own ratio of activity in the three receptor mechanism
  - This is known as cross-fiber coding.