Third lecture

Transmission Lines

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Transmission Lines

In the nerve system, electrophysiological activities of neuronal cells are playing fundamental roles in their information processing ability. The membrane potential, difference of voltages between the inside and the outside of the neuronal cells, varies dynamically in response to the external input or autonomously.

Information processing in the nerve system including the brain is thought to be performed by the transmission of electrical signals in the network of neuronal cells. Each neuronal cell has single axon, the output line, whose endings connect to other neuronal cells.

These connections are called synapses, where electrical signals are transmitted by gradient of chemical transmitters or electrical potential. The neuronal cell to which the axon belongs and the targeted one, are termed presynaptic and postsynaptic cells, respectively. The effectiveness of transmission across the synapses changes depending on various conditions including the timing of the signals transmitted across them. This is thought to be the crucial mechanism for the robust, flexible, and autonomous information processing ability of the nerve system.

Transmission of a signal between neurons is generally carried by a chemical called a neurotransmitter. Transmission of a signal within a neuron (from dendrite to axon terminal) is carried by a brief reversal of the resting membrane potential called an action potential.

Medical Definition of Nerve Impulse :

An electrical signal that travels along a nerve fiber in response to a stimulus and serves to transmit a record of sensation from a receptor or an instruction to act to an effector, the propagation of an action potential along the length of a neuron .

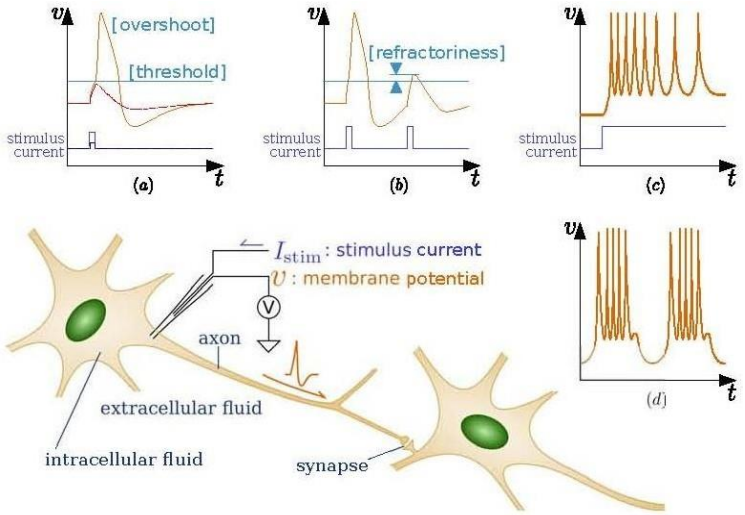


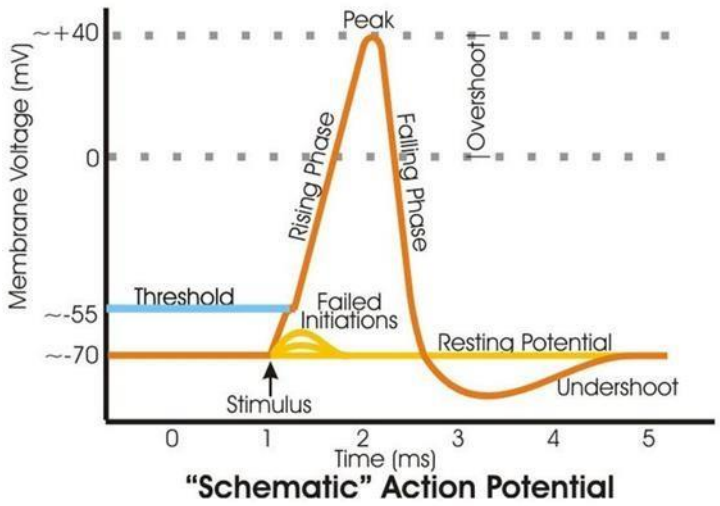
Figure 1. An overview illustration of signal transmission in the nerve system. The membrane potential *v* of the neuronal cell transports the electrical signal. (a) An action potential (overshoot of *v*) in response to a pulse of stimulus current. There is a threshold for *v* , which determines if an action potential is generated or not. (b) If two pulses of stimulus current of the same strength are applied successively and their interval is sufficiently short, the second action potential is smaller than the first one.
This is caused by the refractoriness, the transient augmentation of the threshold. (c) Some neuronal cells fire repetitively in response to a sufficiently strong sustained stimulus. In some cases, the frequency of the firing decreases as it continues firing (spike frequency adaptation). (d) Some neuronal cells produce burst firing patterns endogenously.

A nerve impulse : like a lightning strike, is an electrical phenomenon. A nerve impulse occurs because of a difference in electrical charge across the plasma membrane of a neuron .

Electricity Potential of Nerves :

Because electrical signals are the basis of information transfer in the nervous system, it is essential to understand how these signals arise .

The use of electrical signals as in sending electricity over wires to provide power or information presents a series of problems in electrical engineering .



A Fundamental Problem for Neurons :

1- Their axons, which can be quite long (remember that a spinal motor neuron can extend for a meter or more) .

2- Neuron are not good electrical conductors.

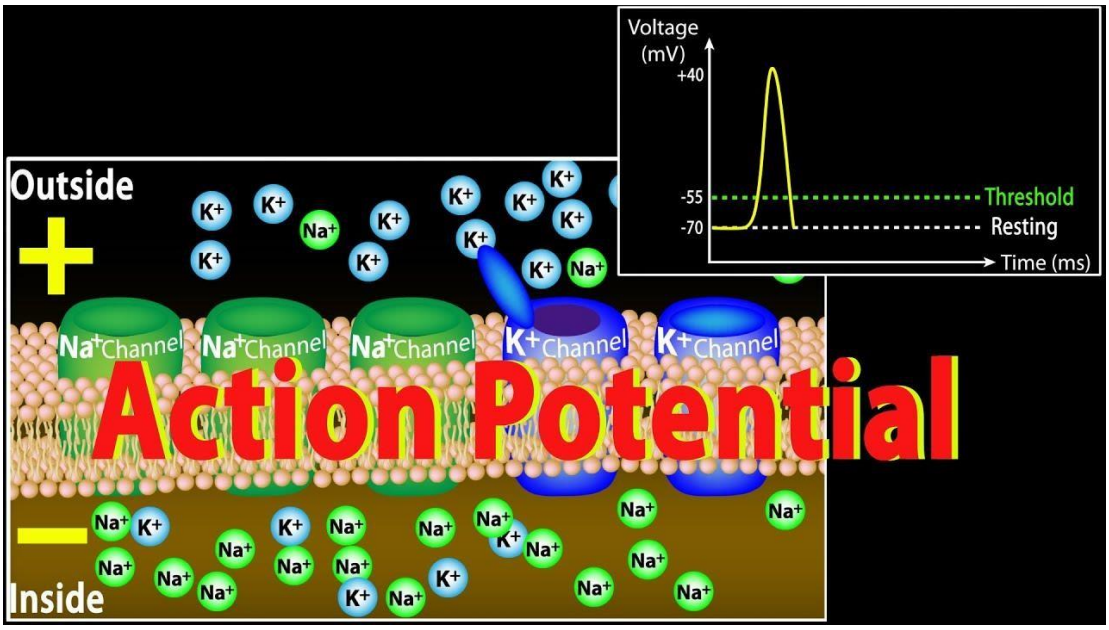
3- Although neurons and wires are both capable of passively conducting electricity, the electrical properties of neurons compare poorly to even the most ordinary wire .

To Compensate for This Deficiency : neurons have evolved a "booster system" that allows them to conduct electrical signals over great distances despite their intrinsically poor electrical characteristics. The electrical signals produced by this booster system are called action potentials (which are also referred to as "spikes" or "impulses) .

Action Potential :

An action potential is a rapid rise and subsequent fall in voltage or membrane potential across a cellular membrane with a characteristic pattern .

Sufficient current is required to initiate a voltage response in a cell membrane; if the current is insufficient to depolarize the membrane to the threshold level, an action potential will not fire. Examples of cells that signal via action potentials are neurons and muscle cells .

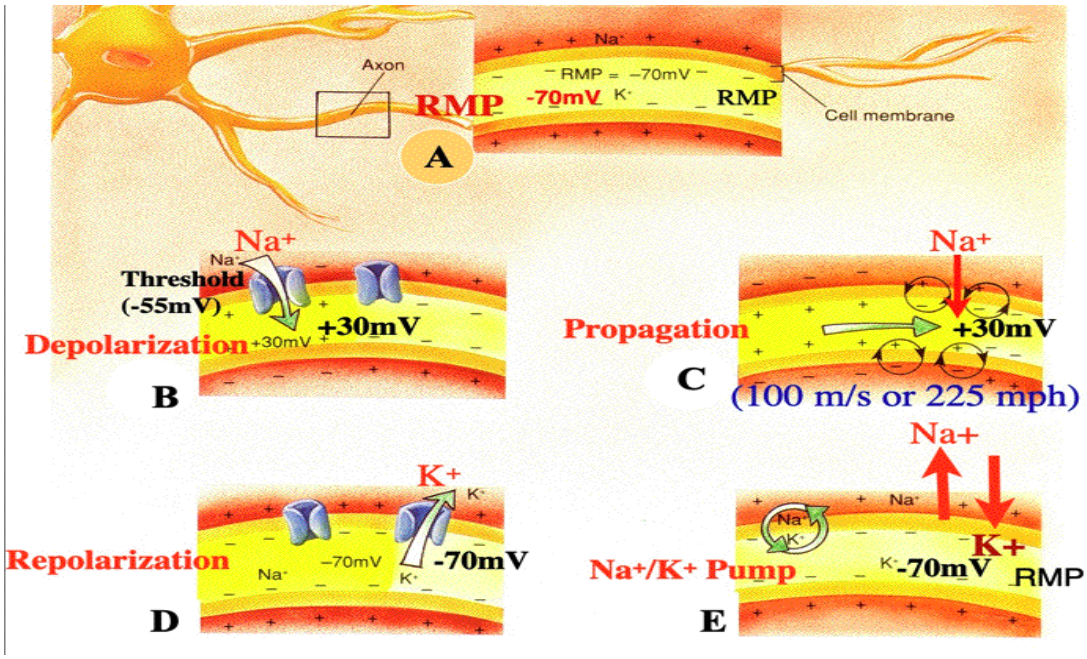


For a long time, the process of communication between the nerves and their target tissues was a big unknown for physiologists .

With the development of electrophysiology and the discovery of electrical activity of neurons, it was discovered that the transmission of signals from neurons to their target tissues is mediated by action potentials .

How Can Generated Neuron Impulse :

A nerve impulse is generated when the stimulus is strong. This stimulus triggers the electrical and chemical changes in the neuron. There are different ions on either side of the cell membrane. The exterior side has sodium ions that are positively charged and are more in number. The interior side of the cell is negatively charged with more potassium ions. Due to this difference in the charges, there is an electrochemical difference .



When a nerve impulse is generated, there is a change in the permeability of the cell membrane. The sodium ions flow inside and potassium ions flow outside, causing a reversal of charges. The cell is now depolarized. This depolarization results in an action potential which causes the nerve impulse to move along the length of the axon. This depolarization of the membrane occurs along the nerve. A series of reactions occur where the potassium ions flow back into the cell and sodium ions move out of the cell. This whole process again results in the cell getting polarized, with the charges being restored .

Neurotransmitters and Receptors :

There are more than a hundred known neurotransmitters, and more than one type of neurotransmitter may be released at a given synapse by a presynaptic cell . Many neurotransmitters also have multiple types of receptors to which they can bind. Receptors , can be divided into two general groups:

1.Chemically Gated Ion Channels :

When a chemically gated ion channel is activated, it forms a passage that allows specific types of ions to flow across the cell membrane.

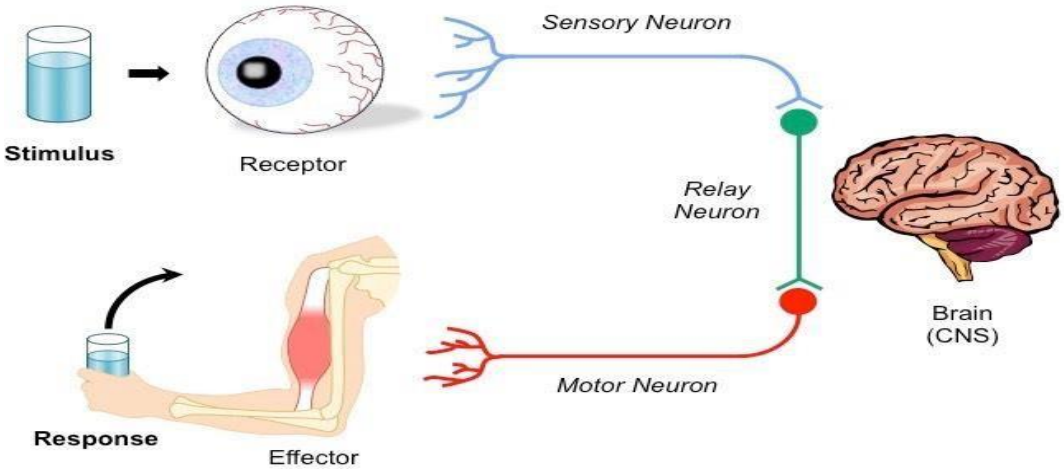
Depending on the type of ion, the effect on the target cell may be :

Excitatory : A neurotransmitter that will have excitatory effects on the neuron, meaning it will increase the likelihood that a neuron will fire an action potential .

Inhibitory : A neurotransmitter that decreases the likelihood that a neuron will fire an action potential .

2.Second Messenger Systems :

When a second messenger system is activated, it starts a cascade of molecular interactions inside the target cell. This may ultimately produce a wide variety of complex effects, such as increasing or decreasing the sensitivity of the cell to stimuli



In 1948, Hodgkin [8] reported that some of the neuronal cells fired repetitively in response to a sustained stimulus current when its strength is above a threshold dependent on the cell. They were classified into two, Class I and II (Hodgkin's classification), according to the frequency of their repetitive firing (see Figure 2).

Table 1. Ionic concentration in the intracellular and extracellular fluids(mM kgH_2O^{-1}).

	Squid Axon		**Mammalina muscular cell**	
ion	**Intracellular**	**Extracellular**	**Intracellular**	**Extracellular**
K^+	400	20	155	4
Na^+	50	440	12	145
Cl^-	40 ~ 150	560	4	120
A^{-i}	385		155	

This is described by the current balance

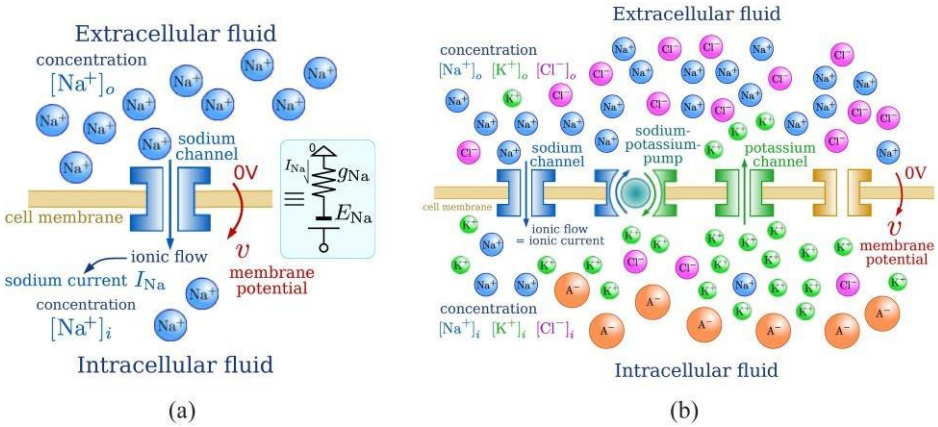
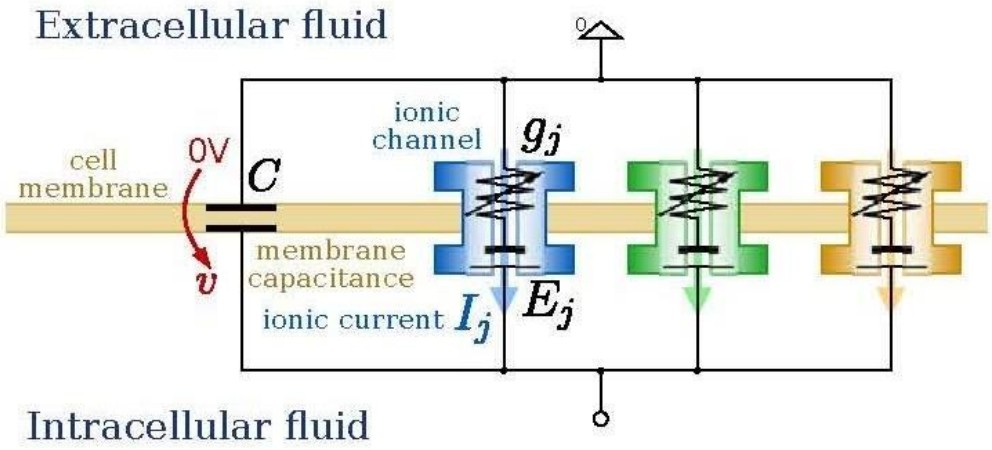


Figure 3. (a) Sodium channel and sodium current I_{Na}. The equilibrium circuit of I_N

shown in the inset. (b) Multiple ionic channels, pumps, and gradients exist across a cell membrane.



QUATIONS

Q_1. An…….. is a rapid rise and subsequent fall in voltage or membrane potential across a cellular membrane with a characteristic pattern .
A. membrane B. action potential C. myelin Sheath
D. resting potential E. falling phase

Q_2 A neurotransmitter that will have …….on the neuron, meaning it will increase the likelihood that a neuron will fire an action potential .
A. excitatory effects B. Inhibitory effects C. resting potential
D. nerve impulse E. booster system

Q_3. Transmission of a signal between neurons is generally carried by a chemical called a…….
A. falling phase B. spikes C. myelin Sheath
D. membrane E. neurotransmitter

Q_4. Central nervous system (CNS) are consisting from brain and ……
A. spinal cord B. membrane C. synapses
D. spikes E. peripheral nervous

Q_5……. made the first contribution in this field in 1786 when he discovered animal electricity in a frog's leg.
A. Newton B. Rontgen C. synapses
D. Luigi Galvani E. peripheral nervous