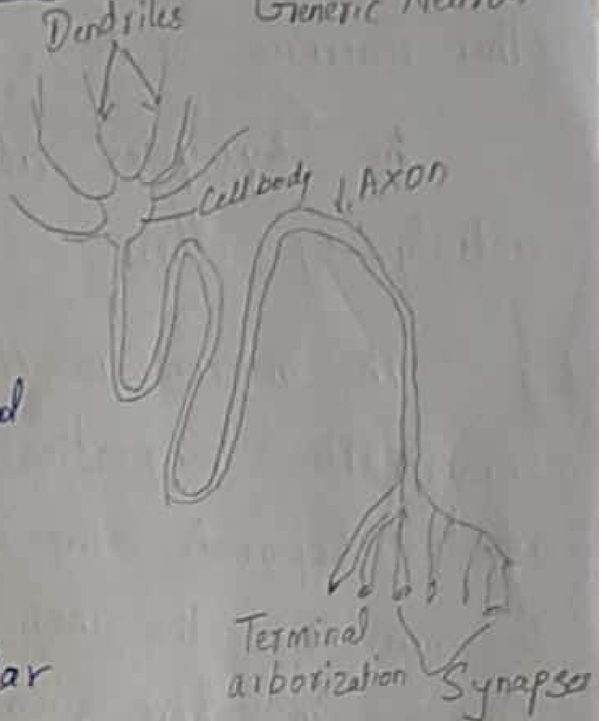
Neural Network



Introduction:

Biological terminology has crept into the ~~new~~ neural network.

The Generic neuron is modeled after spinal motor neurons

Neurons are cells & have a nucleus and the related cellular metabolic apparatus.

One end of the cell, the input end has a no of fine processes called dendrites because of their resemblance to a tree (dendro- is a Greek root meaning "tree"). The cell body is referred to as the soma. Most neurons have a long, thin process, the axon, that leaves the cell body and may run for meters. The axon is the transmission line of the neuron. When axons reach their final destination they branch again in what is called a terminal arborization (arbor is latin for tree). At the ends of the axonal branches are complex, highly specialized structures called synapses. The dendrites receive inputs, and information is transmitted along the axon, to the synapses, whose outputs provide input to other neurons or to effector organs.

The synapses allow one cell to influence the activity of others.

The neuron is covered by a thin membrane with remarkable properties. The function of a membrane is to separate the inside from the outside. In neurons, the inside & the outside are quite different in their chemical & electrical properties. The membrane is only 60 to 70 Å thick & is composed of lipids and proteins. The lipids are arranged in a bilayer in which the protein embed themselves, the proteins float in a sort of lipid sea.

Neural Network:

Work on artificial neural networks, commonly referred as "Neural networks" has been motivated from the human brain.

The brain is a highly complex, nonlinear & Parallel Computer (information-processing System). It has the capability to organize its structural Constituents known as neurons, so as to perform certain computations (eg. pattern recognition, perception & motor control) many times faster than the faster digital computer Ex:

In its most general form, a neural network is a machine that is designed to model the way in which the brain performs a particular task or function of interest, the network is usually implemented by using electronic components or is stimulated in software.

To achieve good performance, neural networks employ a massive interconnection of simple computing cells referred to as "neurons" or processing units.

A neural network is a massively parallel distributed processor made up of simple processing units, which has a natural propensity for storing experiemental knowledge & making it available for use. It resembles the brain in two respects.

1. Knowledge is acquired by the network from its environment through a learning process.

2. Interneuron connection strengths, known as synaptic weights are used to store the acquired knowledge.

Benefits of Neural Networks:

1. Non-linearity: An AN can be linear or nonlinear Interconnection of nonlinear neurons

2. Input-output mapping:

A popular paradigm of learning called learning with a teacher or supervised learning involves modification of the synaptic weights of a neural network.

3. Adaptivity: NN have a built-in capability to adapt their synaptic weights to changes in the surrounding environment.

4. Evidential Response: In the context of pattern classification, a neural network can be designed to provide information not ~~at~~ only about which particular pattern to select, but also about the confidence in the decision made.

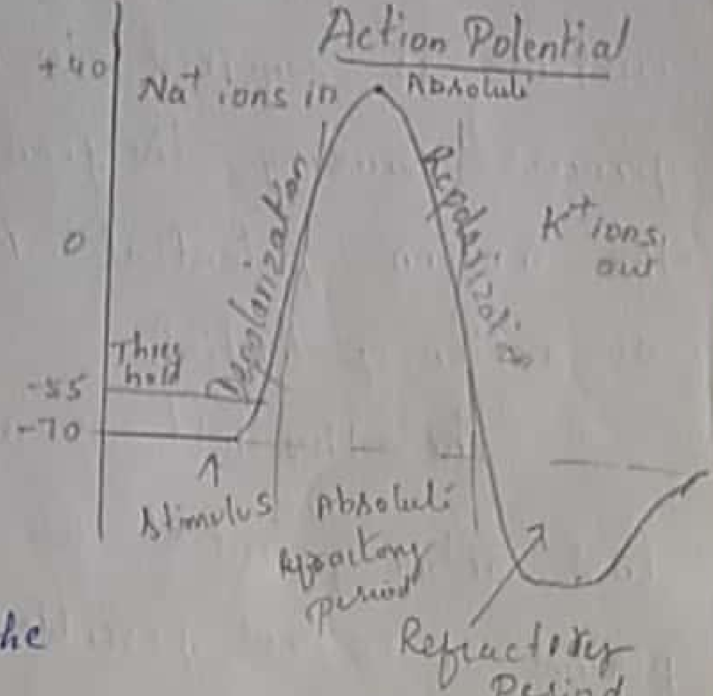
5. ~~Conceptu~~: Contextual information:

Knowledge is represented by the very structure and activation state of a NN. Every

Electrochemical mechanism of the action potential:

Sodium conductance is a function of the membrane potential when the cell is depolarized, the membrane potential becomes more positive & the sodium conductance increases.

The increase in sodium conductance further depolarizes the cell since it moves the cell's equilibrium potential toward the sodium equilibrium potential.



The further increases the membrane potential, causing a further increase in sodium conductance and so on. This positive feedback process goes rapidly to a state at which sodium conductance is very large & cell is near the sodium equilibrium potential. This is why the peak of the action potential is several tens of a millivolts positive.

After a fraction of millisecond of large sodium conductance, the sodium conductance drops drastically, & the potassium conductance experiences a transient increase. The approximate potassium equilibrium potential is restored.

If the increased sodium conductance was not shut off, a neuron could change state only once.

A sharp threshold value of stimulating current is required to provoke the regenerative process causing the feed back process generating the action potential. Below threshold there is no action potential.

The threshold as a func of time after the last action potential, we find that for a brief period it is not possible to evoke a second action potential. This is called absolute  refractory period. For a somewhat longer period after the action potential the threshold is elevated. This is called the relative refractory period.

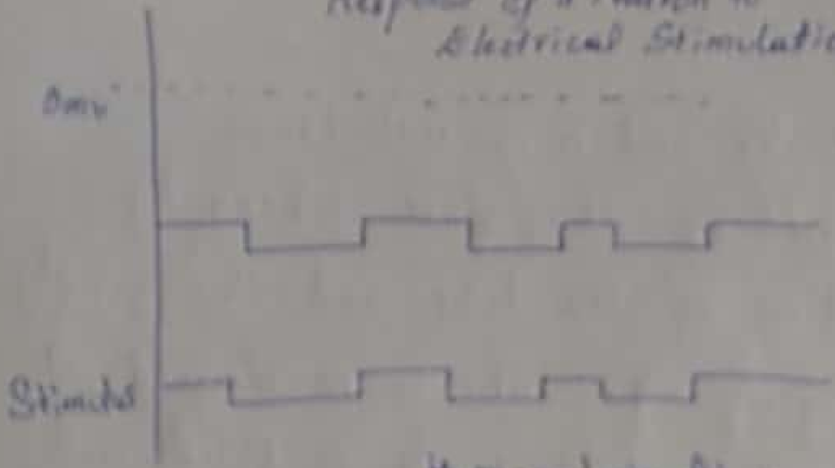
Membrane Potential:

Use sensitive voltmeter and a microelectrode. Microelectrodes are made of thin glass tubing by heating a small portion of the tube and then quickly pulling it. The opening of the tube is maintained all the way to the end. The microelectrode is filled with a conducting solution such as potassium chloride or potassium citrate, forming a high-resistance (megohms) electrode that responds to voltage differences at its tip.

Suppose we carefully push the electrode through the membrane. A sudden change in the voltage occurs, seen by the microelectrode tip as the electrode enters the cell. This is the membrane potential & it is usually a few tens of millivolts between 50 and 90mV would be typical, and depends on the cell type.

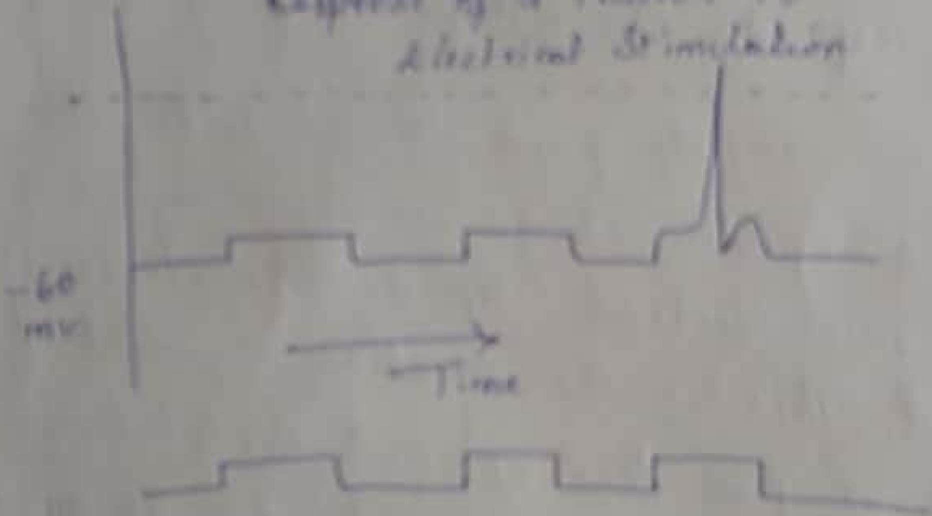
The inside of the cell is negative with respect to the outside. Although a few tens of millivolts does not seem large, since the membrane is approximately 70 Å thick, a -70mV membrane potential corresponds to an electrical field across the membrane on the order of 100,000V per cm. Such a high electrical field corresponds to extreme electrical stress on the membrane & the structures in it.

Response of a Neuron to Electrical Stimulation

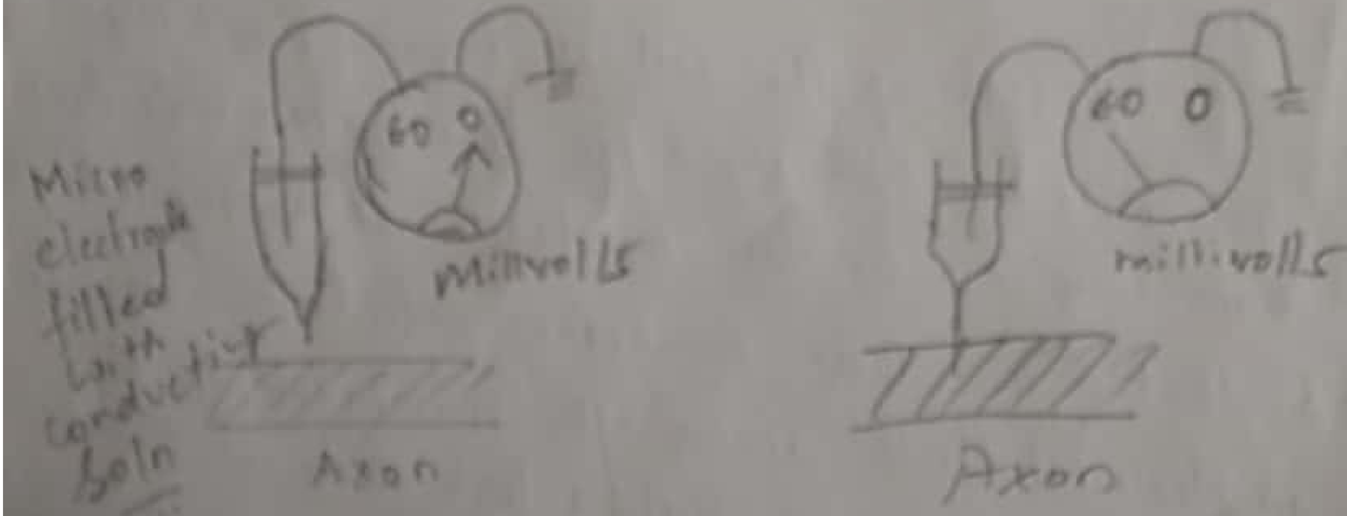


Hyperpolarization

Response of a Neuron to Electrical Stimulation



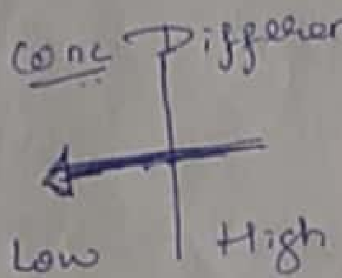
Depolarization



Squid Giant Axon

Outside	Inside
Na^+ (460mM)	Na^+ (50mM)
K^+ (10mM)	K^+ (400mM)
0 millvolts	-60 millivolts

fig: Ionic difference between the inside & the outside of a neuron. Conc are in millimoles (mM) per liter.



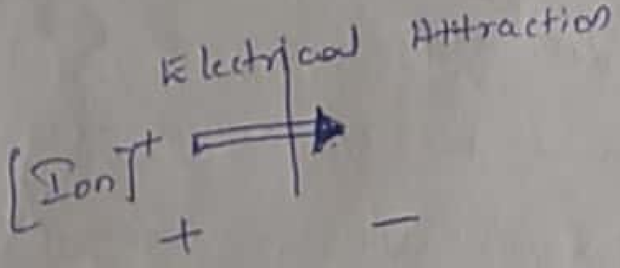
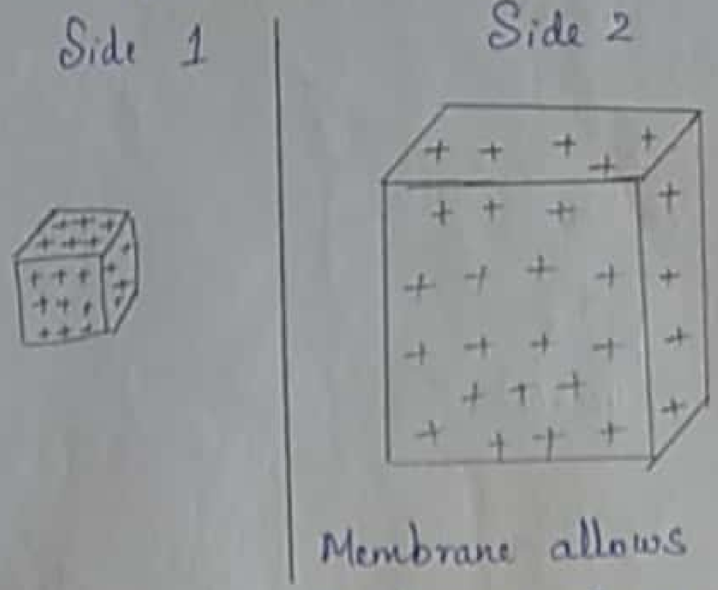
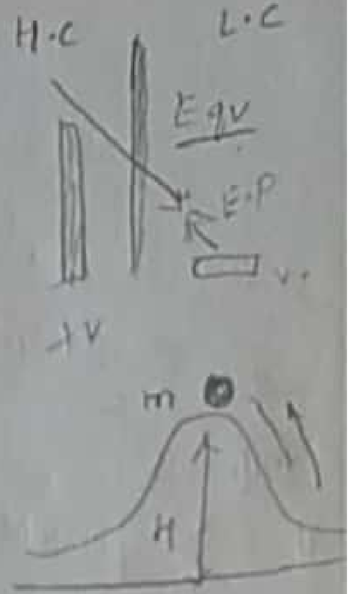


fig: Ions prefer to move from a high conc to a low conc Positive ions are attracted to negative potentials. Equilibrium is possible when the two attractions are equal.

Nernst Equation





Membrane allows passage of some ions

(concentration) times (volume) = No of ions

fig: A very large container divided by a membrane permeable to an ion

The tendency of a positively charged ion to move from a positively charged region toward a region with negative charge could be balanced exactly by the tendency of that same ion to move from a high concentration to a low concentration. To keep them in an area of high concentration, we must supply a voltage to attract them ie a negative voltage in the case of a positive ion. It is this relationship that forms the basis of the Nernst equation.

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We know the amount of electrical work done when a small number of singly charged ions n, is moved from one side of the membrane to the other, across a voltage difference E

work = nEF

$n \rightarrow$ moles
$F \rightarrow$ Faraday constant

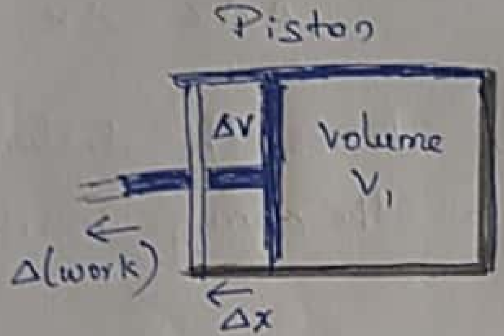


fig: when ions in solution move from a high concentration to a low conc, they can be assumed to act like an expanding gas. The work done in the ionic movement can then be computed.

It is little more difficult to compute the work done when a small number of ions n, is moved from the high-conc side of the membrane to the low-conc side.

no of ions = cV = (conc x volume)

If we take the same number of ions and increase the volume they occupy so it is now V', we reduce the conc of the ions so it is now c'

cV = no of ions = $c'V'$

Assume the pressure is P inside the cylinder & zero outside it. The force on the piston is the pressure P, time the area, A. If the piston moves a small amount Δx, the small amout of work Δ(work) done is given by

$$\Delta(\text{work}) = PA\,\Delta x \qquad A\Delta x = \Delta V$$

The area of the piston, A times the distance it moved, gives rise to the change in volume ΔV

$$\Delta(\text{work}) = P\Delta V$$

From the gas law

$$PV = nRT \quad \text{or} \quad P = \frac{nRT}{V}$$

If we want to know how much work is done when the volume changes from V_1 to V_2 we add up the small changes Δ(work) &

$$\text{work} = \int_{V_1}^{V_2} \frac{nRT}{V}\,dV \qquad \text{log fun}$$

$$\text{work} = nRT \ln\left(\frac{V_2}{V_1}\right).$$ or If we convert the volume into conc

$$\text{work} = nRT \ln\left(C_1/C_2\right).$$

The final form of the Nernst equ, where E is the voltage across the membrane required for equilibrium & C_1 & C_2 are the conc on either side of the membrane

$$E = RT \ln \frac{C_1}{C_2}$$

Synaptic Electrical Events

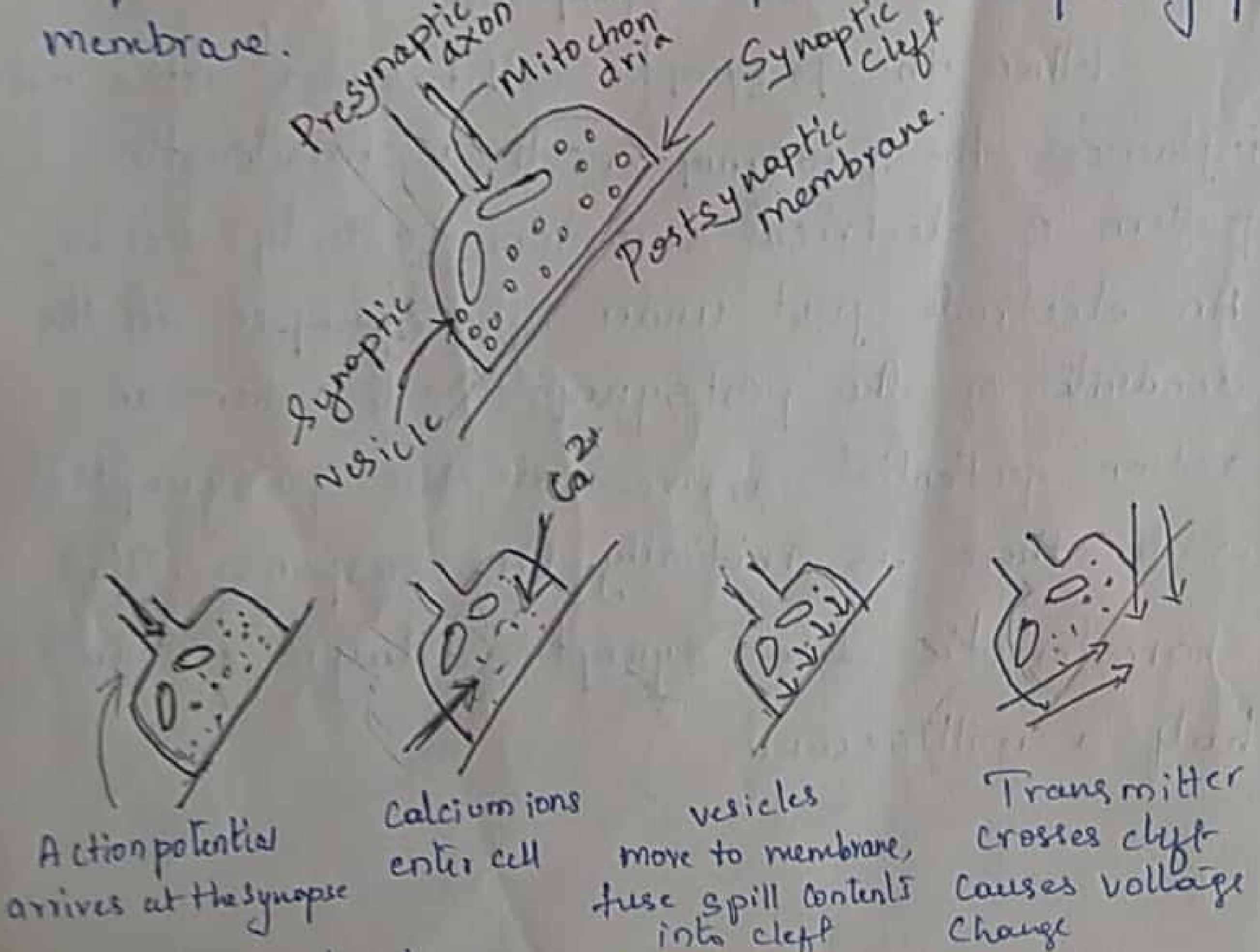
A synaptic junction has two sides. The input side, receiving an action potential from the driving cell, is referred to as presynaptic. The driven cell is the postsynaptic side.

Synapse is at the end of a branch of the presynaptic axon, and that the synapse is made to the dendrite of the postsynaptic cell. In fact, a synapse has a great variety of locations between axons and between dendrities and even an important class of synapses that are made onto other synapses.

When the presynaptic cell becomes active and influences the postsynaptic cell, a characteristic pattern of electrical and ionic activity occurs. An electrode just under the synapse in the dendrite of the postsynaptic cell, when an action potential arrives at the presynaptic side there is initially no response. This characteristic ~~data~~ synaptic delay is around half a millisecond.

First and slowest, calcium ions (Ca^{2+}) are required to facilitate release of the neurotransmitter. calcium ions enters the presynaptic part of the synapse during the increase in conductance associated with the action potential. The calcium ions increases the probability of release of neurotransmitter from the synaptic vesicles. Vesicles fuse with the presynaptic membrane.

In second diffusion process, the fused vesicles release their contents into the synaptic cleft. The neurotransmitter diffuses across the cleft & interacts with receptors on the postsynaptic membrane.



fig; schematized chemical synapse.

After the roughly half-millisecond synaptic delay, the ionic flows caused by the neurotransmitter give rise to an electrical potential in the postsynaptic cell. This is called the postsynaptic potential (PSP). There are two general types, excitatory postsynaptic potentials (EPSPs) in which the synaptic potential tends to depolarize the cell & move it towards threshold, and inhibitory postsynaptic potentials (IPSPs) in which the synaptic potential makes the cell less likely to fire.