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Ion Channels

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Abstract: ***In this we signify the voltage gated channels ions i.e. Calcium, Potassium, chlorine, copper and Sodium. In this we study about these channels how they work in our brain or neural network and how they generate the action potential. In this we relate these channels in different model and how they work in these models.***

Keywords: Action potential, voltage gated ionchannels, neuron network.

1. Introduction

Ion channels are the type of protein which called pore forming membrane. The main function of this protien is to establish the resting membrane protein. The other main function is to give a shape of the action potential and the electrical signals which gives by the flow of these ions channels across the membrane and also controls the these flow by the different cells i.e. secretory cell, epithelial cells or cell volume. [1, 4]

Ion channels are molded of proteins or glycoprotein that tranverse into the cell membrane. These glucoprotein are made of the molecular sugur that attached with the proteins. Each protein are mold by the combination of subunits by itself into a cylendrical form which allow the pore having tube like structure. These subunits are copied of the proteins and combined with the another proteins. These ion channels across the cell membrane through the electrical signals and they does't requiers any kind of metabolic energy. The energy with is required that drives from the chemmical force and these force are like diffsion, electrochemical eqilibrium and osmosis. There are different types of variations of ion channels. Additionaly, the allocations with in the same cell can have abundant variablity, in neuron the axon have larger density of the potassium and sodium ion channels than the others.[1, 4, 9]

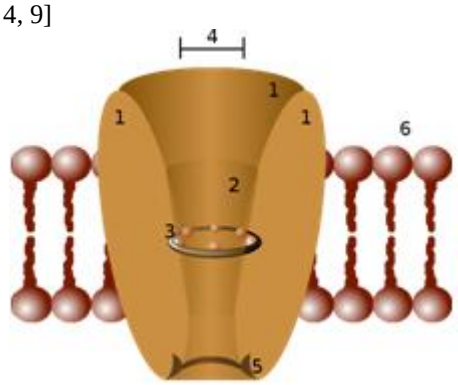

Figure 1: Structure of ion channels

Here, (1) shows the channels domains typically having four channels (2) shows outer verstibule (3) shows selectivity filters (4) shows diameter of selectivity filters (5) shows phosphorylation and (6) shows cell membrane.

We can classify these ion channels by the type of ion in different ways. These are – voltage-gated channels (C_a, K, Na, C_l), voltage-gated proton channels, recepter channels, calcium channels, calcium activated potassium channels, ENaCs (Epithelial sodium channels). We can also classify these ion channels rendering to their sub-cellular localization. Ion channels have different kinds of ion channels blockers. These are-

a) Tetrodotoxin (TTX)
b) Saxitoxin
c) Conotoxin
d) Lidocaine
e) Dendrotoxin
f) Iberiotoxin
g) Heteropodatoxin

2. Leak Channels

When a very few channels (ion channels) were open all the time at this point leak channels occurs or we can say they known as leak channels. These ion channels having different ways or we can say have very complex ways to open and close of leak channels. The formation of channels is charged when ion channels is opened or closed in all the cases sometimes with the energy expenditure or sometimes passively. These changes is totally depends on the types of the channels but it involves the blokade of the pores in all the different cases.

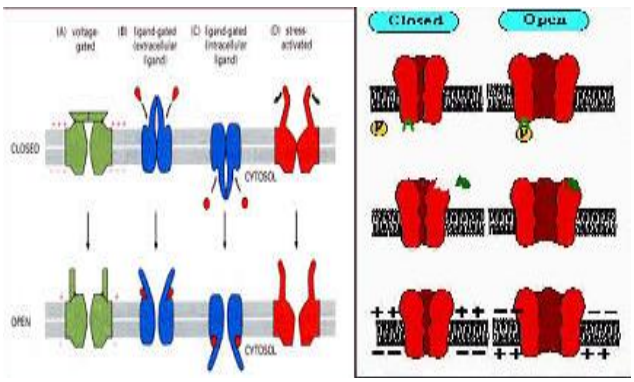

Figure 2: Shows the open and closed function of leak channels

But sometimes these channels change there physical properties inside to the pore and leaving no space for the fluidity of the ions. These changes involves the dissimilar dispersal of chargesinside the pore that restrain the passage of charged particles.In these stages (open or close) channel depends on the signals which are coming through the outside or inside the cells and these are very comman for channels which are controlled by the membrane potential, when these changes occurs then the thresh hold value is crossed.

Receptors is a type of ligand gating channel which consist of proteins that allows the molecule binding and causing the conformation. These channels come out from the outside the cell from the inner cell. The single ion channels have several kind of receptors in different types, thus the result was either opened or closer of the channels. [9] The types of the receptors are complex in nature. The main advantage of these receptors ion channels is the metabolism is totally depends on the phosphorylation by enzymes. The charge does not exist when there is no phosphorylation. When proteins conforms there sub units that the channel is phosphorylation or not.

The main different mechanism of leak channel for open or closing the ion channels:

a) Structural changes is occurred by the protein or phosphorylation and desphosphorylation.
b) Its called direct gated receptors when the neurotransmitter (coupling of a messenger) is in open state.
c) The changes in membrane potential can generate the conformation change and these changes are the voltage sensitive channels. [13]

3. Passive and Active Transport

The small molecules like sugar and ions are transported through the membrane. Cell membrane act as a barrier between the environment and a cell. To move the molecules we required a cell across the membrane. For required energy there are some mechanism for transport. These are Active Transport or Passive Transpport.

Active transport is the movement of the solute through the cell membrane in the contradiction of a concentration gradient, from the state of lower concentration to the higher concentration. Active transport requires energy, which can be derivate through the variation of sources which includs ATP hydrolysis, light, and concentration gradients.

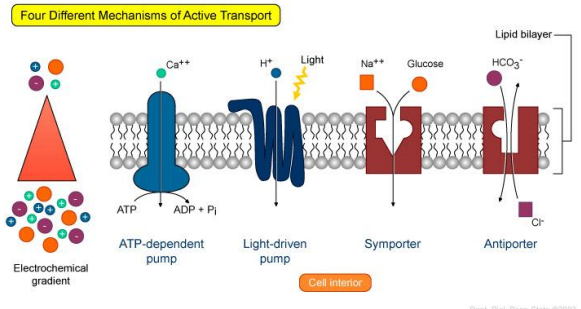

Figure 3: Active transport

There are four mechanism of Active transport

a) The ATP-dependent pump.
b) The light-driven pump
c) The symporter
d) The antiporter

Passive transportis the movement of solutes through the cell membrane down the concentration gradient, from the state of higher concentration to the lower concentration which include passive diffusion, ion channels, and facilitated diffusion. [7]

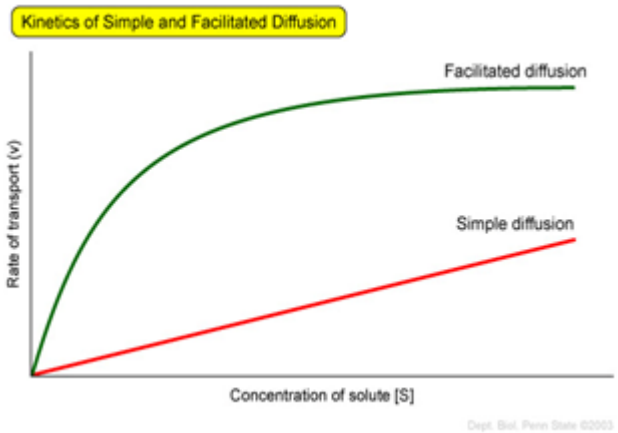

Figure 4: Shows the simple and facilatated diffusion

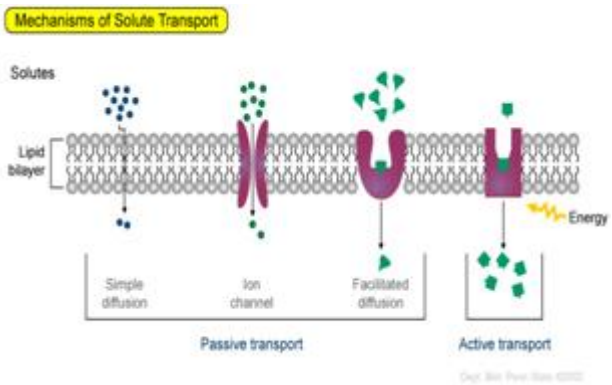

Figure 4: Shows the mechanism of solute transport.

In this fig first part shows the passive transport of the solute diffusion and second part shows the active transport solute diffusion. Simple diffusion is the independently diffusion of a lipid-soluble solute through the lipid bilayer. When these transport channels passes through ion then it involves a protein pore.

Transport past an ion channel involves a protein-lined pore traversing the lipid bilayer across the selecting ions which are transported. This diffusion includes a solute which shown in green color triangle in the figure through the membrane by carrier protein which shown in purple. Active transport contains a solute which shown in green squares against the electro-chemical gradient by pump protein and this process required energy.[7, 9, 13]

4. Classification by Gating Ion channels

Ion channels are classified in different methods. These methods are by gating, by ionized or by cellular

localization. In the gating ion channels the ions are depends on the open or closed state.

There are two methods of gating ion channels:
a) Voltage- gated ion channels
b) Ligand- gated ion channels

In **voltage-gated ion channels** the closed and open state depends on the voltage through the plasma membrane. There are three channels in voltage gated ion channels.
Voltage-gated calcium channel (Ca^{2+})
Voltage-gated sodium channel (Na^{+})
Voltage-gated potassium channel (K^{+})
Voltage-gated chloride channels (Cl^{-})

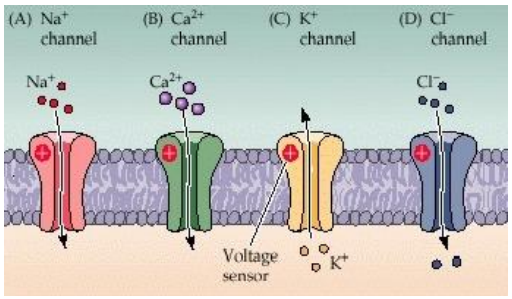

Figure 5: Shows Voltage-gated Ion channels

These channels propagate and activate the action potential and convert into electrical signals.
Mathematical equation of voltage gated ion channel is

$$I_m = C_m \frac{dV_m}{dT} + \overline{g_K} n^4 (V_m - V_k) + \overline{g}_{Na} m^3 h (V_m - V_{Na}) + \overline{g}_l (V_m - V_l) \quad 4.1$$

$$\frac{dn}{dt} = \alpha_n (V_m)(1 - n) - \beta_n (V_m) n \quad 4.2$$

$$\frac{dm}{dt} = \alpha_m (V_m)(1 - m) - \beta_m (V_m) m \quad 4.3$$

$$\frac{dh}{dt} = \alpha_h (V_m)(1 - h) - \beta_h (V_m) h \quad 4.4$$

These gated ion channels depends on the activation or in activation if ion channels and represent in electrical signal which known as action potential. There are various models which represent the action potential using these voltage-gated ion channels. Like HH model, Integration and fire model, Calcium model etc. [2, 6, 5, 8]

In **Ligand-gated ion channels**depends on the receptors. These receptors are in the group of trans- membrane that allows the ion channels through the membrane and response in the binding of ligands, like neurotransmitter.

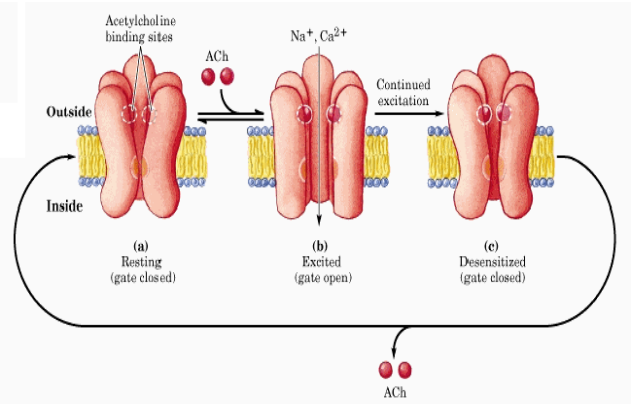

Figure 6: Shows Ligand-gated ion channels

When neuron release the neurotransmitter from vesicles then binds to receptors and placed on the neuron or postsynaptic neuron. The resultant of these changes opens the ion channels and flow through the cell membrane and the excitatory receptor response shows depolarization and inhibitory response shows hyperpolarization. There are different types of receptors. These are:
a) Cys-loop receptors
b) Cationic cys-loop receptors
c) Ionotropic glutamate receptors
d) AMPA receptor
e) NMDA receptors
f) GABA receptors
g) 5-HT receptors
This receptor acts as a protein in cell and receives the chemical signals outside the cell. [2, 6, 7, 9]

5. Diseases due to the Absence of the Ion Channels

There are several disorders due to the absence of the functioning of the ion channels. These disorders or known as channelopathies. Defects due to the absence of voltage gated channels are: Shaker gene, Equine hyperkalaemic periodic paralysis, PAM (potassium-aggravated myotonias), FHM (Familial hemiplegic migraine), PA (Paramyotoniacongenita) Cystic fibrosisetc. [7]

6. Conclusion

In this paper we study about the ion channel and the classification of ion channels. In this we also mentioned the various diseases or disorders which occurred due the absence of these ion channels. We also described the mechanism of these ion channels in our brain and study about the gating ion channel which helps to converts chemical signals into electrical signals or in receptors. In this we also characterize the protein feature that is transporter differentiate them with another proteins features. When ion channels passes through the membrane then the ion uses transport (Active or passive transport). This transport helps to converts lower concentration into higher concentrations or vice versa.

References

[1] Hille, Bertil "Ion Channels of Excitable Membranes" ISBN 0-87893-321-2
[2] Robert J. French and Gerald W. Zamponi "Voltage-Gated Sodium and Calcium Channels in Nerve, Muscle, and Heart" VOL. 4, No.1, March 2005.
[3] Gene Family "Ligand gated ion channels" HUGO Gene Nomenclature Committee.
[4] Camerino DC, Tricarico D, Desaphy JF "Ion channel pharmacology". Neurotherapeutics April 2007.
[5] Purves D, Augustine GJ, Fitzpatrick D, Katz LC, LaMantia A, McNamara JO, Williams SM (2001). "Voltage-Gated Ion Channels", ISBN 978-0-87893-742-4.
[6] Purves D, Augustine GJ, Fitzpatrick D, Katz LC, LaMantia A, McNamara JO, Williams SM "Voltage-Gated Ion Channels", ISBN 978-0-87893-742-4.
[7] F. M. Ashcroft, "Ion Channels and Disease", Academic Press, San Diego, California,2000.
[8] Payandeh, J., et al., The crystal structure of a voltage-gated sodium channel. Nature,2011. 475(7356): p. 353-8.
[9] James Huettner "Ion channel".
[10] RizaErdem,CesurEkiz, "A Kinetic model for voltage-gated ion channels in cell membranes based on the path integral method," Physica A , vol. 349, pp. 283-290, 200.
[11] Robert J. French and Gerald W. Zamponi "Voltage-Gated Sodium and Calcium Channels in Nerve, Muscle, and Heart" VOL. 4, No.1, March 2005.
[12] B. Sakmann and E. Neher, "Single-channel recording", B. Sakmann and E. Neher, Eds. Springer, 2009.
[13] Hille B, Catterall, WA "Chapter 6: Electrical Excitability and Ion Channels" 1999. ISBN 0-397-51820-X.