<u>Title: 공학도를 위한 생물학 (3)</u>

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[00:00]

So today we are going to talk about the regulation of neuron system, basic properties of neuro-generator.
And later chapter 3 ?[00:27], very basic pattern of this neuron membrane.

Chapter 4 you need to know act of properties, different classes and related work, so.

But in chapter 4 we'll discover the action of the form particular.

So for today, hopefully basically physics is kind of chemistry.

We'll be covering a little bit after that, and also added quite along with that.

So first of all, just review about water and ions.

So information flow in neurons depends on ion, which ions dissolved in water.

Water is polar molecule so that means there is separation of positive and negative polar action, but they r

And so as we've seen before, in a water molecule there is the negative charge difference and the positive

And water it shows, shows that there is pretty mentioned before long.

And ions my definition, positive charge or negative charge.

And so an important ion physiologically are sodium, just one positive charge, potassium, also one positive

So these ions are dissolved in water which means the water, it pushes associated with the ion, so the… u

But… so in case of sodium ion the oxygen matters with cluster rounds the sodium.

The oxygen, the negative charge.

And the hydrogen atoms in water molecule, stay away from sodium. Hydrogen atoms have positive charg

And so sodium chloride, of course just the salt, salt in water, sodium and chloride separate from one anot

And each of those atoms, the sodium atom and chloride atom are surrounded by water molecules.

The word hydrophilic means, comes from Greek it means, water lover, and it is the chemical that likes wa

So dissolves in water, and the water helps to balance the particular charge.

So the salt, sodium chlroride ion, dissolves in water, because it's hydrophilic.

Hydrophobic or lipophilic, means, hydrophobic means literaly water fearer.

[05:00]

So molecule that is not like water.
Lipophilic means, first the molecule relax back, essentially hydrophobic, lipophilic personalities are synon

These molecules do not attach to water, because they have evenly balanced electrical charge, they don't

And so it does not dissolve in water.

And they do dissolve in fat, fat or ?[05:41].

And many biologically important molecules are amphiphilic, which means they like both.

So they have parts of molecule are, hydrophilic and the other part is hydrophobic.

And one example of this, familiar amphiphilic is salt.

Salt dissolves in water because water enters the salt molecules, hydrophilic, which it has charges,

At the end the salt molecule dissolves in fat and so salt molecule dissolves fat and water, ?[06:34] water a

And many biological molecules have this property.

Some part of molecule like water and some part like fat or lipids.

And proteins in general are like this.

They have hydrophilic and hydrophobic domains.

And another example is phospholipids.

Phospholipids are [07:05], which is hydrophilic and lipid, on the other hand, lipid is the carbon chain, whic

And the cell's outer membrane is a phospholipid layer.

So that's not that all unit is ?[07:31] phospholipid.

As I just said in language, phospholipids have a polar head and a nonpolar tail.

So polar heads charged, hydrophilic and nonpolar tail is not charged, hydrophobic or lipophilic.

Unfortunately, I have not yet, I haven't ?[08:08] what the ?[08:13].

And these are interesting parts of my body.

Some might not see this well, but there are phospholipid molecules and this is the phospho section of neu

And these phospholipid molecules are bi-layer, one layer here and another layer here.

And the heads, the polar heads are phosphate groups.

The phosphate is the phosphate flow of oxygen, has negative charge.

And these are the nonpolar lipid tails.

So they like away from water, so the phosphate here, this is all, here, phosphates interacting with the wat

And interacts in lipid part of the phospholipids and the other relative.

So they have two layers, one membrane has two layers, and exposed to water are phosphates on each s

And water and ions they do not pass through the vaseel ?[09:56].

It interacts with phosphate molecules but the water and ions they do not like to be exposed to the nonpola

[10:00]

And that is just because the water molecules like water molecules, and sodium ions like water molecules,
So this property of the ?[10:35] theory, it's important because it provides the basic for separating electrica

And that is needed for molecular signals. There's..

It's also important that there are lipophilic aspects, that pass through membrane.

So the molecules that dissolve each layer, fats, ?[11:10].

And there are quite ?[11:17] about this property.

Artificial membranes… they are also ?[11:24] some substances, physiological substances about this prop

And ?[11:32] that pass through membrane.

And then particularly important type of molecule, most important type for regulating molecules, is this is io

So ion channels are proteins, and this goes kind of review of the chemistry approaches.

And I'm not willing to do that, hopefully more to study something about structure and function approach.

And ion channels are just one of many types of proteins.

They are found in the membrane, in phospholipid bi-layer.

And so this hopefully already haven't studied, that means this part of ion channel the protein molecules a

Well, this part, is outer, outside of molecule is hydrophilic,which interacts with the outer solution.

?[13:05]

This part also ?[13:10] fluid, but the inter side, ?[13:12].

And the typical ion channel has 4 or 5 membrane subunits wich are shown here in different colorants.

And there… and… kind of symmetric relationship, the center is a core of ion channels.

The actual channel for the ions to pass through.

So sodium, potassium go through that ion channel, they cannot pass with ion channel.

There are very important feature of ion channels.

They have some ?[14:16] activity, so they don't distract any ion pass ways or molecule.

They essentially just have one type of ion pass through or so… ?[14:27].

But postive charge ions but none negative charge ions.

And the opening and closing of ino channels allows for information to be ?[14:46] electrically.

So it is very important to understand how ion channels open and close ?[14:59].

[15:00]

We won't be discussing that today.
Another very important molecule in memebrane is ion pumps, which is shown here.

These facilitates ions across the membrane, pump ions across the membrane.

But to do this, they consume energy from ATP.

And they cause the ions to go upper ratio that they can take sodium ion.

For example, low concentration of sodium ion inside and high concentration outside, a sodium pump acro

And most famous and important for the physiological function is sodium-potassium ATPase.

The ATPase is an enzyme that degrades the ATP, ATP to ADP.

And it faciliates ?[16:25] the potassium into the self.

So that's what's shown here.

Because of this sodium pump, sodium tries to get outside for the inside.

What's shown here is sodium binding, from the protein, from inside itself and potassuin then released insi

Potassium leaks form the inside of the cell.

And than ATP is drawn down, so that causes trancport to pump changes concentration and now sodium(

So this is, so that the energy and ATP is converted in this way ?[17:35]equibalant.

And ionic gradiant that is difference in concentration of ions across the cell membrane.

And that difference in laying concentraion act like a battery.

It stores elecrtochemical energy, which is used for elecrical signaling in brain.

So there are two very important factors that influence the movement of ions.

The movement of ions.

And the first of this is diffusion.

Dissolved ions distribute evenly.

The space there, the ?[18:35] allows ?, so what's showed here? , the center here possible by there.

And to the left of the concentration concentrates with the sodium chloride.

So the sodium ions and chloride ions distribute evenly through the water.

And than, if sodium channels open and chloride channels open, sodium would flow to, sodium channels o

And evnetually, the concentration ? of sodium and chloride, on one side of the membrane is as same as o

And that's called diffusion.

So ions flow down concentration gradients, so ?[19:27]

And as I said before, channelsare selectively permeable to some ions and not others.

And the second infactor is the movemants of ions make voltage, with electrical ?[19:49]

So the electrical force on an ion caused by a difference in the spatial distribution of charge, around.

[20:00]

So if one side of membrane is ?[20:05] more positive charge to negative, than sodium like to be pushed a
And that will cause the sodium ions move.

So the voltage, voltage just reffers to potential or electrical potential, and of course we will be able to real

So the potential energy acting on a charged particle.

And so measured in volts.

So a battery has some voltage assosiate with it.

So one end of battery have positive charge, called anion, on the other hand, negative charge called catio

And so the potential difference, voltage difference between two end of battery.

The current reffers to the amount of charge movements per unit time.

And so measured in Amperes, so amps.

And the resistance reffers to how easily charged particles can move in the particular environment.

A wire would have some resistance associated with the wire's produce of electricity force ?[22:03] system

Possible ?[22:08] with very high resistance.

So the charge particle do not move easily through it.

A resistance is measured Ohms.

And conductance it's just the inverse of resistance.

?[22:29]Anyway people usually talk about resistance, rather than conductance.

But in physiology, you see, easier to reserve conductance rather than resistance.

And conductance measured in Siemens, although that's actually not ?[23:02], quantify conductance.

So Ohm's law is certain relationship between voltage, current, and resistance, ?[23:22]

So the V equals, the voltage equals current times resistance.

For the ?[23:34] the conductance g, inverse the resistance.

So 1/R

And so you can also write that the voltage equals the current divided by conductance.

And there are certain conventions that are important, you should memorise.

The direction of movement of positive charge corresponds to a positive current.

And a cell, the flow of positive charge from inside to outside a cell corresponds to positive current.

So if potassium ions flow out the cell, that will be a positive current.

That's also called that's also ?[24:46] currents, where as if the sodium flows into the cell, that would be a

[25:00]

And each way of a cell, the outside of the membrane is more positive charge, than inside.
So that's shown here.

This is a small peice of a membrane that the outside has a positive charges, like a membrane inside has

And this byconditional membrane patential voltage ?[25:41]senseitve negative.

And we couldn't like for the inside of the neuron and measure the voltage difference between inside and o

Typical value ?[25:54]

And very important concept is about equilibrium potential.

So as we discussed ?[26:24]

Sodium(Na+)/potassium(K+) ATPase pumps Na+ out of the neuron, and K+ into the neuron.

So therefore, Na+ is high outside of cell, and K+ is high inside.

And another very important feature of neurons is that the membrane is permeable primarily K+.

Primarily K+ pass through membrane very easily.

But other ions not pass through include sodium.

So what showed plot it is the potassium is high on the inside of the cell, and low on the outside.

And than if potassium ?[27:20] situation, there are no ion channels, so in that case there won't be any cur

Potassium won't move.

And now if there are some ion channels in membrane, and these are permeable ?passage

The potassium tend to flow around the cell, so that the positive potassium falling out.

And eventually because potassium pass out of the cell, there will be positive charge of outside membrane

So the K+ flows down its concentration gradient that is out of the neuron, until the build-up of positive cha

And when that point reach, and ?[28:19], that is by definition K+ equilibrium potential.

So ? concentration gradient, because potassium is higher from the inside of the cell, and lower in the outs

But eventually the potassium, than the charge more positive on the outside of the cell, from the inside.

So the electrical from of potassium is causing to go from outside to inside.

And in this two, when the electrical force, and ?[29:08], and difusion.

It goes to more balance, the potassium is that equilibrium potential.

And real neurons, disequilibirum potential has ?[29:32]

In case, we have membrane permeable only to potassium, and it would be a voltage difference across th

[30:00]

?[30:01] we come back that...

So the electrical properties of a neuronal membrane can be modeled as what's called “equivalent circuit.”

And that's showed in here problem, electrical circuit ?[30:20]

The circuit has a battery, and act, batteries act as a resistor and a capacitor that are parallel to another.

So the battery is...

It charge separation across the membrane, because that's graded by sodium(Na+) potassium(K+) ?[30:4

So here is this diagram, the battery, ?[30:59] battery, here ?[30:01] and there, so voltage difference acros

The battery corresponds to the ionic gradients maintained by ion pumps, the resistor, from here correspo

So more ion channels are opened in membrane, the lower resistance, for greater in ?[31:41]

And capacitor corresponds to the membrane capacitances.

So this this is the signal for capacitor electronics, and capacitance, the membrane has capacitance becau

It's thin, and charge accumulates on membrane.

Because of positive effective charges interact with each other through the membrane.

So there is region on one side of membrane, negative charges, positive charges from the other side of th

And so the voltage fly across the membrane.

The voltage change across the membrane current of flow.

And it takes time for voltage change because of capacitor, so capapcitor acts as store of charge.

So the voltage differential across the membrane, charge of flow, some acts are kept flow of capacitor in a

So what showed here is appling to voltage to the membrane.

And you see membrane voltage across the membrane changes, it doesn't change ?[33:25], it takes some

And the typical neuron, the time and tense, what is one state of myocytes, so the one-milli second, or son

So the membrane voltage does not change spoontaneously, because of capacitance of membrane.

And this is something the textbook doesn't talk about.

But I want to say...

I also want to point out that…in, my goal in teaching is not, not so many in equations.

So there are a lot of equations, all these equations to explain the dynamics of the membrane voltage.

But I want you to understand the standard, understand the two in front.

This textbook does not do a good job, it doesn't even really try to…to describe the biophysics in many de

And I'd like you to tend a little bit more to the textbook but…I will not ask…well, I may ask some mathema

[35:00]

But I want you to understand intuitively, I want you to understand or be able to at least understand the qu
So Equilibrium Potentials can be calculated using the Nernst Equation.

And Nernst Equation takes into consideration the charge of the ion, so whether it's positive charge, negat

And it takes into consideration the temperature.

Also this is not... a physiological variable.

At least in mammals the temperature would be well over constant.

And it takes into consideration the ratio of external and internal ion concentrations.

So these ion concentrations are very important

But under normal physiological conditions, they don't change.

And they attain that pulse, constant levels because of the ion pumps, the, because…at large number of m

And we're not gonna talk about all those mechanisms.

And we predict that the ion concentrations is just the process.

So all of these things are essentially [?37:02] to change the equilibrium potentials is at constants.

The equilibrium potential is also often called a reversal potential.

I was trying to say that a little bit later why it's called reversal potential.

So this is a Nerst Equation.

The equilibrium potential of an ion species is equal to all these constants…multiplied by the moderate of t

So these constants are R that's the gas constant, T is the temperature in Kelvin.

And it's [?38:02] from absolute zero.

Z is the charge of the particles so with sodium it's +1, with chlrodie -1, calcium it's +2.

F is Faraday's constant and [?38:20] it's not so important you know exactly what all these are.

And for a particular ion, this will just be some constant, this whole term.

And this is the natural logarithm, concentration outside and the concentration inside.

So one thing that's complete in this equation is the concentration outside is equal to the concentration ins

So if the equilibrium potential of an ion is not zero, only because there's a concentration difference across

So here is…a table showing the actual concentration of ions across the membrane.

So as I said, concentrations are very highly regulated so that they're essentially constants.

So this is the, and you should know something about…which ions are more concentrated on which side o

So it's important to know that potassium is concentrated on the inside of the cell…twenty times as much o

[40:00]

Sodium on the other hand is concentrated on the outside of the cell.

Calcium is very concentrated on the outside of the cell, there's ten thousand times more calcium on the o

There's almost no calcium at all on the inside of the cell.

And chloride is concentrated on the outside.

So from these concentration ratios it's possible to calculate the equilibrium potential using the Nernst Equ

And the Equilibrium Potentials are written here.

So the Equilibrium Potentials of potassium is -80mV.

Sodium…well, now these days it varies a little bit from one cell to another…or one animal, one species to

So…potassium is -80, sodium is +62.

Calcium is 123, +123 and chloride is -65.

And different textbooks have slightly different numbers.

But these Equilibrium Potentials you should memorize.

They're very useful and…you should definitely memorize them.

The concentrations you don't need to memorize exactly but what you should memorize is sodium is conc
inside.

Chloride, actually, I think it varies…a bit.

So chloride, these concentrations of chloride, I believe it change very…which is interesting and has some

So Goldman Equation is…used as the Nernst Equation.

And the Nernest Equation is just concerned with simple type of ion.

So you could, you have Nernst Equation, potassium and another equation for sodium and another one fo

And as I said, there's the, main…membrane, the cell membrane's mostly permeable to potassium.

But it's also permeable to other ions.

So that means it has a lot of potassium channels but it has some other type of channels also.

So sodium channels, chlrodie channels.

And so to calculate the membrane voltage, potential difference across the membrane, we use the Goldm

So Goldman Equation quantifies how the membrane potential depends on the conductance of each type

Sometimes the word 'permeability' is used to study conductance.

And permeability is technically the more correct term.

But it's, I think, easier to think about, talk about conductance rather than permeability.

So it's typically expressed in terms of ion concentration and permeabilities.

It looks very similar to the Nernst Equation, except that it includes multiple types of ions so…larger equati

But it can also be expressed in terms of conductances and equilibrium potentials.

And I think this is the more…it's more useful when you think of it this way.

So here's, here is expressed in terms of conductances and equilibrium potentials.

[45:00]

So this equation…G is conductance and E is equilibrium potential.
And so Gk, Gcat conductance of potassium conductance are also [?45:17] and Ek is potassium equilibriu

And if for reasons that don't really matter to us now, well, this has, Gcat and Ecat…but you can…think of

So this, if the membrane is, has just, just permeable or has conductance to sodium or potassium, then thi

So this is the conductance of a particular ion multiplied by the equilibrium potential for that ion…plus [?46

And this is…so it actually uses [?46:21] voltage across the membrane.

But this is a, the steady state voltage.

So that's [?46:30] by this infinity symbol here, is the [?46:35] or the voltage term.

So what that means is that the membrane voltage will approach this collateral.

And in a real ion, these conductances are changing.

They change quite rapidly like scale off a middle center.

And the membrane voltage they never reach the steady-state value.

So you could write a differential equation of…to calculate the membrane voltage dynamically.

And with that, the membrane voltage will always be approaching the steady-state but like never reach it.

And these conductances would be changing all the time.

So if you look at this equation…so you can magnify, you can imagine that if potassium, not only the potas

And…well, I just said one way to think about this is this is like weighted average of the equilibrium potenti

So if the sodium equilibrium potential's about plus, well if I say, +50 millivolts, and potassium equilibrium p

Let's say that the sodium…what this actually, this cat actually refers to a cat ion, the equilibrium potential.

And there are some channels that are permeable both to sodium and potassium.

And it doesn't matter whether exactly what this channel is permeable to.

Let's imagine that the equilibrium potential…here, we'll call the sodium is zero millivolts.

And the potassium is -100.

And the actual voltage there, steady-state voltage will be the weighted average of those two.

And…weights will be in numbers.

So, if the two conductances are equal…equal conductance or permeability to both sodium and potassiu
potentials.

But if they, if the... potassium conductance is twice as high as the sodium conductance…

So then the, this value's, so if this value is two and this value is one, then we work through this equation a

[50:00]

So it would be more average weight towards potassium equilibrium potential rather than the sodium equil

But of course, if I only have the potassium conductance, the membrane voltage would be, be at potassiur

So the [?50:42] the, the passive membrane of the real cells in neurons, there is very permeable to potass

So increasing the Potassium concentration ?[51:07] more on busy line, little shift ?[51:11] potential on po

?[51:15] equational and people ?[51:20] membrane.

So this shifts membrane potentional in neuron as functional passive, external passive ?[51:34].

So the normally the passive concentration, external passive concentration is like while memberane…

Got this passive nodes, passive ?[51:51] cell.

And membrane potential in neuron closes passive potential membrane in neuron.

So as we express?[52:02] real neuron for its ?[52:04] define roles.

So that means?[52:07] voltages around ?[52:10].

It's a little bit or more polarized if there's some ?[52:18].

But not my ?[52:22].

Anything that has ?[52:25], it causes large ?[52:29] organization membrane ?[52:30].

So deep polarization shifts pole to zero ?[52:37].

So membrane voltage in neuron ?[52:42] hyperpolarize to make line 65 or ?[52:50].

As it shifts positive reactions or to zero, 60 polarize.

So very often ?[53:00] polarize neurons.

They are simply polarize ?[53:05] neuron detach means.

It's not so easily ?[53:14].

And I said normal admissions, it doesn't have ?[53:24] concentration is very high, so externally ?[53:30].

And if you're doing the same things with the sodiums, increasing sodium concentrations.

That would cause some polarization as well, but very slow.

That's neuron does not ?[53:55] membranes sodiums while just acts lot as a sodium concentration gets.

Here's an additional points about ?[54:18].

For one instance, there're large changes in membrane voltage.

These are certain ?[54:29] very small or negligible changes in ionic concentrations.

So the ionic ?[54:39] a large ?[54:42] across membrane.

So you can have a lot of test?[54:48] as falling out with their neurons ?[54:51].

So that's not a large ?[54:54] in larging ?[54:55]memberane voltage.

Very large in chains ?[54:59].

[55:00]

But that's not correspondent to larger chain concetrations of optimizes.
So where the ionic concentrations little fits ?[55:20] but it just ?[52:23].

Small changes of neurons concentration survives ?[55:27] very lot of chains ?[55:29].

But next difference in electrical charge ocuurs at inside and outside of membrane surface.

So that shows, here…

An exceeded positive charge ?[55:47] the outside of the neuron membrane and they decharges ?[55:52]i

And membrane itself is very small ?[55:59] earlier out?[56:01] neurons.

And concentrations away from membrane charges ?[56:15] balance.

So there's positive ?[56:18] ranges ?[56:19].

And only outside of the membrane has difference in charge.

In a very important ?[56:41], is current, rate of movement of ions, across membrane is proportional to the

So the diving force is difference between ?[57:00] in membrane and E collaborated potentional ?[57:04] i

So at the time and so ?[57:08] so called ?[57:12] neuron is normal state.

The voltage across the membrane ?[57:20].

And passively elaborated potential is alliance at 85.

And so diving forces will be line 65 minus 85.

So plus ?[57:42].

So calculating passive currents plus membranes back to shown in here, it's a passive in ?[57:59] multiply

So the greatest passive ?[58:12] is great occurrence, greater diving force, the greater ?[58:17].

?[58:48] much cost, structure of an ion channels.

And this book doesn't always ?[59:01].

But this shows ion channel here in membrane ?[59:14] structure in ion channel.

And this was the first channel experiment this studies, a voltage-sensitive K+ channel are called as "Shak

And this called ?[59:33] like a clump ?[59:35] called Chaker because channels domain from mutions ?[59

Then it has a four sub-units, the 4 ?[59:54] polypeptides, which interact each other, so its shape.

[60:00]

So the center of them, ?[1:00:10] or that would ?[1:00:13] minus ?[1:00:14].

And this channel studied structures of channels studed by Robert Mackinner and gets the Nobel Prize, de

And it uses a ?[1:00:37] a lot of these and mutations ?[1:00:40].

The mutations ?[1:00:44] structures of the ion channels.

This slide doesn't really fit this lecture ?[1:00:55] chapter 4 as same as ?[1:01:03].

They don't ?[1:01:06] very much.

Lot of ?[1:01:10] of saying couple of another ?[1:01:14].

Line of this ion of channel ?[1:01:26] to form an ion channel ?[1:01:29].

So they are charging electrical ?[1:01:36] inside of…or in this case this is active collectifier of channel lite

Better addditive charge ?[1:01:54].

Essentially the size of pore ?[1:02:02] appropriate to allow passive ?[1:02:04] testers testing the particula

And dio?[1:02:18] has ?[1:02:21].

And here's channel different type of testing channels, but they have they all have pore reaching channels

So if you don't need ?[1:02:44] have sequence of channel, ?[1:02:49] the sequence.

Recognize the different channel might ?[1:02:59] certain new essence.

The certain sequence of new essence.

And if you have this channel the voltage sensitive which has ?[1:03:13] discussing that ?[1:3:16] later.

?[1:03:20] molecules better inside the membrane.

So ?[1:03:30] suppose the voltage across the membrane.

So took parts more than ?[1:3:42] minus acting pore and the voltage sensor.

And they back they now ?[1:03:55] they know exactly what this things are.

And free pressure to model this ?[1:04:06].

?[1:04:06] also have…

You can also have it studied this conservation rule ?[1:04:17].

?[1:04:18].

And even watch the horizontal axis might pull passive ?[1:04:28] channel.

You can see the changes which is conformation, very high conformation.

So microseconds.

That is dampy ?[1:4:44] any types of proteins.

So it's ?[1:04:57], concluding remaks in chapter 3.

[60:00]

We discussed passive electriacal properties of a neuron's membrane.
But a neuron's membrane properties are also exactly active or some of other properties are active.

And as I said before its differences, passive or active of neurons ?[1:05:23].

But active property of memebrane does not ?[1:05:33], just ion channels already closed.

So that's dynamically processed.

So ?[1:05:42] everybody ?[1:05:44].

It's not all possible ?[1:05:50] of neurons ?[1:05:53] passive neurons.

And a basic biophysics then integrates actually the same both ?[1:06:10].

So I think ?1:06:20] perhaps I would ?[1:06:23].

?[1:06:26].

?[1;06:36] very good, straight forward study.

?[1:06:46].

So I thought it just ?[1:07:12] or show you what ?[1:07:20] close ion channels for you projecting ?[1:07:26

So this is currence of cell and this axis is times, so this would be positive nuerons.

And that would be caused by minus channels opening the membrane.

Pottasium channels just open membranes.

For it caused by projecting channels ?[1:08:39].

So the life inside ?[1:08:43].

And the voltage producing…you have a ?[1:08:58].