Title: 공학도를 위한 생물학 (2)

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[00:00]

Okay, today we'll start nervous system.

Usual way to teach this is just go right into the cells and molecules and unite chemistry and biology followed.

I think it's better to say something to start about the purpose of the nerve system.

What is it trying to do?

And I hope you to understand the develop, first framework of laboratory ?[02:03], the function.

And everyone agrees that the nervous system is system for processing information.

And when I say that to you, probably, you'd say of course that's what it does, and also that statement mean nothing to you.

It doesn't have any access that ?[02:35].

And I have my first degree about neuroscience and phD in ?[02:47] and developed 1 or 2 years after my phD that I discovered that more information, actually hasn't definition.

According to ?[03:03] uses, we all know something about what it means.

But I didn't realized that actually that formal definition and the program I was in was very much ?[03:22].

And it wasn't ?[03:26] informtaion processing or ?[03:28].

And I think it's more important to understand something about what information is or tyring to understand what nervous system is.

And ?[03:42] information process and computational function compared.

So I was able that to start with information and general function of nervous system.

First I'd like to talk about general computational theory of the nervous system.

So there is no accepted general theory of the computational function of the nervous system.

If there were, then it should be in textbooks and in textbooks, you don't see anything about it.

In fact, in that textbook and all the other textbooks threre are no, particularly, specifically computational text books, computational neuroscience textbooks, but there is general nervous system textbooks.

You won't find anything about definition of computational theory

This is biology and neuropsychology.

But if there were accepted general theory about computational fuction of the nervous system, it'd be in textbooks.

[05:00]

But there isn't one.

And the textbooks don't even discuss the idea that would be a general theory.

?[05:21].

And I think many people believe that there never will be a successful general theory.

The nervous system is just too complex and does a lot of different things and there is no general, there are very few general principles about this computational function.

And last year I actually proposed a general theory about it, however, few people know about that.

And it cannot be very easily proven or disproven.

I mean it can't be tested but it's not, you know, there isn't simple test to prove it right or wrong.

And just recently I thought of another principle, it was not in the theory, it was probably missed, and so I don't consider the theory as complete anymore.

But I still think that it is mostly correct.

So I just wait until another ?[06:39] and there will be hard time that I'll finally cover in this cover, but in this course will focus on basic neuropsychology.

And it's not, I tell you understand that it's neurophysiology that we can understand really really well.

So, I want to say few things about general theory, what is a general theory.

First thing we have to do general theory about how nervous system works, is test to identify a singly computational goal for the entire nervous system.

Or single function, but this is function of informational process.

And we have to quantify how the nervous system achieves that goal.

And we need to explain the nervous system's connectivity, and it's connecting between neurons, wider or some connections with other connections, and we also need to explain temporal dynamics, temporal patterns of activity that is seen in nervous system.

And that is essentially the physiology of nervous system, we need to explain that.

So it's the special temporal structure of nervous system.

And it should describe the fundamental principles necessary to construct an artificial system.

So why has there not been a general theory of the computational function of the nervous system?

And common answers to this question are, but the question is it's not a best question.

But if you are to ask this question, common answers given are the nervous system is too complex to be explained by a general theory.

And because ir performs too many computational functions to be explained by any single theory.

So the computational fuction, so their major computational function do not give, explain the all ?[09:26].

And another common answer: we don't yet have enough about it, we need know the particular ?[09:36] form, the "miring diagram", just means connections between neurons.

There are a lot of connections, and we have not studied them in great detail.

But the answers that I'll give to this question is, first, very few people have tried to develop a general theory.

[10:00]

It's not something that is talked about a lot, I've never really talked about it actually.

And the second reason I think is, particularyl important is…

Many scientists do not have a clear understanding of information, and information really means very kind of related to probability theory.

So that's the similar state most scientists don't have clear understanding, of the probabilities.

And most neuroscientists actually don't even studied information ?[10:37], they are studying ?[10:41].

So they can do very well all about asking this types of questions.

A smaller number of neuroscientists maybe 10%, study the computational work, that is work ?[11:01] about information found really of importance.

But in fact, there is disagreement about the definition of probabilities.

And that's not, nothing specifically do with neuroscience.

Just in science, mathematics, there is disagreement abou thte definition of probabilities.

And therefore also about definition of ?[11:34].

And the third reason is scientists, they focus on understanding, they focus on describing there own information about nervous system.

And that's mostly what we are going through this course.

We'll going to describe what we know about nervous system.

What they don't usually do is to ask what the information brain the nervous system has about this world.

And that is, that information the brain has got the world,   what is puriable for its function.

It can't be ?[12:20] that informational science has got brain.

But it doesn't, what you don't know doesn't matters to the world, somehow you may know.

So scientists usually take their own respective on nervous system, and they consider inputs and outputs.

And they kind of figure out the relationship between inputs and outputs, and state chemical and biological connectiveness.

But they don't, they don't think very much about what information there neurons about the world.

And I think taking that respective, it's critical understanding the earth.

And a quite easy way to make this point is to ask…

Having you think about difference in how do you view world as a scientist, and as a person.

So this is very obviously in our lives as people, about scientists, we are very often try to predict behaviour about the people.

We do this all the time.

And one…, obviously to predict ?[13:46] one information the person has.

That's the main problem trying to get to people just to know what information they have.

We already know a lot about people, you know they don't really ?[14:04] on money, ?[14:05].

The goals are fairly common to all of us.

But different people have different information, so they behave differently.

And that's very different from totally related to science.

At science, you probably understand, to study person's behaviour, and make some mapping between the persons, environment inputs and ?[14:38] outputs.

And you thinking about this, it is useful to do that, of course, watching person day after day.

And trying to figure out about what they are likely to do based on the patterns observed.

But first in process, the person you are studying is constantly in new situations, and you can't just rely on past conformation.

[15:00]

And this is actually important principle in psychology.

It is called "period ?[15:15]".

And childrens develop, and "period ?[15:15]" means understanding other people have different lines, they have different information than I have.

And young child cannot understand that, and ?[15:30], they gain that understanding that's about the age of 4 or 5.

And there is theory of autism that says that autistic children, they don't have really nerves.

And theory line is also something that they stopped all the unique humans

So animals don't seem to ?[16:01].

So I think studying nervous system is important but to take the respective of the nervous system, the firs-person respective, instead of third-person respective.

So what is the computational goal of the brain, what is it trying to achieve in terms of processing information?

So this is a picture of a child of ?[16:40], here is the child and these are all different types of candies.

And the child is just tyring to choose from these candies.

And this is obviously difficult for the child, if you have your own self experience.

And typical thing is the child doesn't really know the ?[17:00] of different candies, unless she has experienced all those different candies.

And has to try to choose one of them and needs to, has to make their values somewhat…

How much worth value, each candy to have.

So they are making decisions, it's very difficult because the uncertainty of values of those candies.

And this is actually the same computational nervous system always faces.

It's not always candies, it's now always the problems about which a person's conscious most ?[17:40] what nerve system does, it's unconscious.

But the nervous system has to select some equal outputs.

And has to do that based on the value of the outputs.

And the problem will be in psychological terms for decision, problem decision.

And this is the kind of situation that we can use.

That's the problem that we don't really think about.

Or maybe something ?[18:16], even problems we are consciously aware of.

But there many many decision making process we are not consciously aware of.

But still nervous system must select some outputs for behaviours instead of others.

And the problem making these decisions is always uncertainty.

Something it has… But the nervous system selecting motor outputs or making decisioins and does that to promote future biological fitness.

So biological fitness comes from ?[18:58] all areas.

Biological goal is not like as many consciously thinking about, I mean deciding the type of candy to buy.

But that is biological function of the entire animal, but obviously the function of the nerve system.

And I refer to that future biological fitness as reward, future performance…

If you are ?[19:30], it's not easy to say exactly what future biological fitness is.

First thing we have to do general theory about how nervous system works, is test to identify a singly computational goal for the entire nervous system.

It’s similar to how many great great great parents have, but…

But the problem it may position is always that there is uncertainty seemingly world, specifically about future reward.

And uncertainty is just another way to say the uncertainty is the lack of information.

[20:00]

So what is information?

We are not going to spend much time in this.

This is not physiology class and you don't need to cover all physiology.

But it's important to know there is a definition of word information,

A mathematic definition to define it as reduction in uncertainty.

The information is basically the reduction of the uncertainty.

And uncertainty is defined from ?[20:53].

So the uncertainty refers to the worth of a predicability distribution.

So uncertainty refers to the width of a probability distribution.

So the wider distribution, the greater uncertainty, and the lower the information content.

And appropriate measure of uncertainty is entropy.

And you don't need to worry about ?[21:18] about mathmatic ?[21:19], but the ?[21:24]

And this is published 50 years ago.

And that was start of what's called information here.

So here is some free probability distributions, the probability distribution is allways ?[21:51]

And that's actually has been executed in the past.

Some people ? probabilities to just to say as frequences, physical features of neurons, masure of frequency ?[22:9]

But the ? distribution is that it is probability or probability ?[22:19].

And more information have narrow distribution.

So the distribution here in red, is ?[22:32] flat compared to the other distributions.

And so it has less information.

And narrower distributions, here, this has more information goes into.

And if there is no information at all than you can see flat by every possible state, or value through it all is equally right.

That's the complete difference ?[23:05]what's like to be proven.

And it's actually possible to, at least in simple cases, to specify information in a molecule.

So this is the molecule of a Retinol.

?[23:35], and this is the photo sensor in the eye, in our eyes.

So this photo sensetive pigment is ?[23:50] attaced to ob?[23:53].

And when a proton strikes the molecule changes from the cis-donformation to trans-conformation.

And that is the first step in the process of visual.

And so that conformation change in that molecule, that information goes all the way up to the brain, and that's how received

And ?[24:29] possible, it's acually ?[24:31] information in terms of ?[24:37], and to do that the ?is necessary to specify ?[24:42] distributions.

And so in this case, ?[24:48]

So you just know the conformation of this molecule, and that is information that is in molecule of course.

[25:00]

And just in case of information that molecule possible to guess what the light sensor is.

And an energy diagrams of a different states of molecule.

And you can specify probability of those states, states that molecules, using what's called Boltzmann’s Equation, statistical statics,

No we are not goning thorugh this, it's not goning to be in test.

But, if it specifies probability of molecule being one state to another, depending on the energy of the states.

And ?[45:48]lightest mean? molecule.

And so these know that the sensors in the on conformation, you can guess what ?[26:00]light visions are?

In this case this is actually done for voltage sensors, photo sensors.

So the molecules in one state, you can guess high molecule ?[26:16] high ?biosensitivity are much more probable than low ?[26:18]

And for molecules on the other state guessing ?[26:23]

And obviously there are a lot of uncertainty, right?

You can based on conformation that molecule you can say high light ?[26:31] what is more probable for low ?[26:34]

But you have many other of this molecules, and you have information about the conformation of those molecules.

Then you can come up with a probability ?[26:51] of something more like this.

So the ?[26:55] sensors will be "on" or "off"?

And if ?[27:00] functioning clearly means this functions gather again like this.

So now ? can guess very, very probable, that the light ?[27:11] voltage ? small ?

And that is the reduction of uncertainty.

Because we don't know anything about the state of molecules, and this happens to guess at all light sensetivity, through all molecules ?[27:32].

And you can maesure that by the ?[27:40] uncertainty, and you can compare that case of the hinderance,

The flatest distribution is ?[27:47] distributions, calculate ?[27:50] and take it differently and that's the information.

And I think the ?[27:54] is ?something interesting, actuall measure that information ?[28:03] the neurophysiologest ?

So the next what I want to say and to think about, ?[28:20] in order to function of brain

So I got ?[28:25] this is the photo cell, this is sensing lights.

And you ?[28:30] change through the whole reactions.

You can face in that information from the eye, all the way up into ?[28:38]

And in that processes, there are many, many, many chemical ?[28:45] so we have...

The information got out ?[28:49]

And of course, when you are making decision, about what to do, it's not that useful to know what the light sense is in some smaller sense of space.

So that information is very ?[29:05] used.

What the brain needs to know in order to make decision, is about this abstract notion or reward.

That's what decisions, needs to be faced on.

And so next, the sensory receptors around body a many few types.

These sensor receptor provide this sort of the crude information, it's by itselves ?[29:39]

And brains take that infomation and relate it to reward.

And that's the basically what the of barins source.

Obviously ?[29:54] sensor receptors.

So here's a simple sensory neuron pathway.

[30:00]

So this is from a touch sensetive receptors in finger tip.

In the spinal cords, and that's one neuron, there, they are actually I can't see very well,?[30:24]

Actually that neuron goes all the way to fingrer tip, has a cell body here, to the spinal cords and projects up to barin stam.

And there is other neuron, goes from there to there, thalamus, and another neuron ?[30:40] cortex, another neuron from somato sensory cortex, motor cortex, and another neuron, that spinal cord to ?[30:52] neuron from spinal cord out to muscle.

So that is a sensory motor move.

And there ?[31:04] can be drawn, from the same from this sensor receptor to this motor neuron there are other ?[31:11]

And some goes pathways shorter, and to just to come to the spinal cord, and others are longer, long process in cortex.

And how long the pathway is ?[31:36] contains seneory neuron itself.

So I'd wanted to ?[31:51] these a taste.

The taste of sugar, ? taste of somthing bitter,

That is a lot of reward information that tells you, you can swallow, or spit.

?[32:04] and you spit it out

And so this really short pathway, taste receptors in the tongue, to the muscles that control swallowing and ?[32:23] or spitting.

So taht's a in short pathway, with a few neurons.

Few neurons from sensory to the motor.

As you move from sensory neuron, you get information very formed from sensory indformation to about sensory neural like biosencetivity to bring reward informations.

And so the reward informations, critical to the ?[32:53] , what the motor ?[32:55] need.

So in case of a taste, the pathways are short.

That can be long pathways as well, and you can ?[33:07] a long time thinking about this.

But, ?[33:11]

But for other sensory ?[33:16], the pathway ?[33:18] longer, and visions are good example about it.
So light sensetivity are really, very uninteresting, it doesn't really matter not much as life ?[33:27], and there are some pronimant uses for light sensitivity in ?[33:35] simple organisms, like in bacteria would have some sensitivity of lights.

But for most of what our brains do, biosensity is ?[33:45]

And you get information, reward informations about life ?[33:54] requiers a lot of processing.

And so if ?[34:00], the eyes here, and a number of neurons containing eyes and motor system, muscles it could be a large number.

So just in the eye alone , information ahs passed through these free neurons before ?[34:18] the eye.

That it goes to thalamus and than ?[34:25] pathway goes to visual cortex, but than it goes one neuron after another through cortex, before it gets to the motor neurons.

But the long…

So, I think I ?[34:45]

So some sensory stimulies that contain a lot of reward informations.

And these do not need a lot of neural processes, so the sensory, the short path to the sensory inputs ?[35:03]

[35:00]

And example is taste.

Which is detacted as concentration of a chemical in the mouth.

So the concentration reported chemicals in mouth, a lot of reawrd information.

But,?[35:19] sensity because a lot of ?[35:26]

O.K so that's, thats all what I wanted to say about the general ?[35:35] of definition information, and something about the organization general function of neural system.

So now we are going to go into basic function of neurons.

And as I think you all know, neurons are basic units of neural system.

And so understanding anything about the nervous system is in system you must first understand the function of single neurons.

So this shows something about the structure of single neuron.

And the first ?[36:20] is neuron is very similar to any other cell.

Most of all happens in neuron happens in any other cell.

And main genes that are reported to function as neurons also important for other cells.

And ?[36:35]

So neuron has nucleus, DNA, transcription, translation, protein trafficking, mitochondria, and on and on.

These processes are all the same as any other cell.

So the ?[37:02] to be questioned 'how are neurons different from other cells?'

And perhaps it is obvious differences in morphology.

So they have this protrusions coming out from cell body.

They have dendrites which is the, like you see in here, mostly dendrites coming off the cell body in the center.

They have axons, which are another type of process brifly talking about ?[37:36]

And they have synapses which is specialise in junctions that communication between neurons.

And the second feature, the expression of a great diversity of ion channels and associated proteins for regulating membrane voltage.

So the regulating membrane voltage is very important in neurons.

The other neuron, other cells also regulate membrane voltage of at least little bit of ?[38:11] ion channels.

And there is a voltage difference across in membranes.

By ?[38:22] into dynamic way, there is not so many different ion channels, so neurons specialise in this.

There is also important to recognise muscle cells also have a lot of ion channels, and membrane voltage is very important to ?[38:39] muscle cells.

And muscles and most neurons are said to be “excitable.”

And that means that they produce action potentials.

?[38:52] about action potentials.

But I'll save it for right now.

But there is no single physiological feature that distinguishes all neurons from all other classes of cells.
So some neurons do not have dendrites, some of neurons do not have axons, and they don't have action potentials either.

So those are, most all allowed to do ?[39:35] fast neurons have those features, and some doesn't.

And some non-neuronal cells also have action potentials, muscle cells...

And other cell most release vasicals with chemical neurotransmitters.

So that's something that all neurons do.

But other somato cells do as well.

[40:00]

So now ?[40:14] and structure of a prototypical neuron,
So it has ?[40:21] soma, soma, the word soma just means, comes from the latin or greek, for body.

And ?[40:30] is called cell body.

And than word ?[40:35]

The cell body is about 20 μm in diameter/

Some are small as 5-10 μm and some are large to 50 or so.

The axon is, well so, looking at the figuar there, so that is the soma of course.

The axon shown in here.

And the axon is, I believe it is ?[41:23] to neurons ? to every neuron.

But I ?[41:28] there is no other cell type that has an axon and ?[41:34] of axons.

Is specialized for communiction of the neuron’s output across distances.

And some axons in humans are as long as 2 meters.

And the 2 meter long axons are very special.

You won't find this in brain.

But the…[?42:03] in the cattle, has an axon from the toe to the cell body at the spinal, just outside the spinal cord, here in the tail bone, close to the tail bone.

And then it changes right past the cell body upto the base of the brain.

So that's just one cell, so it goes that distance and it's…you have some idea how big it is, [?42:35] information, right?

Because you have experienced them.

And if something happens…and axons in other, suppose axons in whales will be much more than that long.

The dendrites are shown here so these are the dendrites coming off the cell body.

And the word 'dend' comes from the Greek word for 'tree'.

So it's called dendrites because it looks like a tree.

And each are specialized for receiving synaptic input from other neurons.

And in general, the larger the decorative tree, the more synaptic inputs the neuron receives.

So to go back to the example of the neuron that goes to the toe, that neuron gets its inputs just from small region of the toe.

And the action synapsis, those inputs connect directly to an axon.

Now that's a neuron stop to the cell body but just goes right past it, never even, the information never even, well I suppose it does reach the cell body but it just goes right past it like driving on a highway, a major highway right past the city without a stop.

And so that neuron has no real dendrites, it doesn't look at all like this.

And in the other special, other structure that's found in neurons is the synapse.

And the synapse, well the synapse is at the end of an axon.

And it's a specialized junction for communication between the axon of one neuron and the dendrite of a cell body of another neuron.
And so that's a synpase right there, this is the axon of one neuron forming a synapse with another neuron.

[45:00]

Something else I forgot to mention is that usually there's just one axon coming off from the neuron, from the cell body.

In some, in some special neurons, there's more than one axon coming off the cell body.

And very often, there is just one axon coming off but [?45:29] split into multiple collaterals so they're called collaterals.

So that's what's shown here, this axon is one axon becomes multiple axons.

So I, probably you already know this but I'll just take again the flow of information within a neuron.

So information flows into a neuron from its dendrites, travels down the neuron axon to a synapse and then on to another neuron.

And one neuron will release neurotransmitters or chemicals or the small chemicals.

[?46:32] will open ion channels at synapses on dendrites of another neuron.

And the opening at the ion channels we like to call an impulse…in the neuron.

And these electrical impulses or synaptic inputs are integrated in the membrane voltage.

So they will add the other or some of the other to determine the membrane voltage.

And when membrane voltage crosses the threshold, there is an all-or-none action potential generated in the axon.

And it's actually generated…and so this neuron, I believe this is the axon right here coming… from, I can't be certain…but these are all dendrites and so one axon.

And the point toward the axon is joined at the cell body, it's called the axon pellicle.

And I [?47:41] called pellicle, I've never seen the word anywhere else.

But that's what it's called.

And at that point, that's the point where the action potential is generated, at least generated in the neuron.

That action potential then travels down the axon…until it reaches the synaptic terminal where it triggers the release of neurotransmitters onto another neuron.

And it's of course, to point out, that some neurons do not have action potentials or axons…or dendrites.

Axons and action potentials are specialized for communication across distances.

And most neurons need to communicate across some distance but there are some neurons that do not.

And very often neurons that do not need to communicate across some distance do not have axons or action potentials.

This is a subject that I think is very important and so we're going to discuss it in detail or later.

So…it's probably not clear to you now why axons or action potentials are important for communication across distances but you should understand that by the end of the course

And in fact some, one small animal is studied a lot C. elegans, so this is a little worm that's studied particularly because it's very easy to manipulate its genetics.

And that worm has about 400 neurons and none of those neurons have action potentials.

So there's a lot of talk about action potentials in the nervous system, there is some people who are very [?49:53] about action potentials…digital information processing but in fact…it's only really important when you have to communicate across distances.

[50:00]

It's not [?50:08] function, basic function of the nervous system.

Of course, in our nervous system, it's very important to be able to communicate across distances so in that sense, it's very important but it's, it's not a necessary aspect or nervous system function.

So how are neurons different from one another?

So they differ in their morphology.

So here is a drawing from Roman y Cajal, very famous Spanish neuroanatomist from a hundred years ago.

And this is a drawing from neurons in cerebellum.

So these are all found in the part of the brain called the cerebellum, [?51:11] there's many different shapes and sizes.

So they have different morpologies.

And then the second difference is the synaptic connectivity.

So each neuron has, essentially each neuron has its own unique synaptic connectivity.

A typical neuron in the cortex has about ten thousand synpatic connections.

Or I could say receives about ten thousand inputs, synaptic inputs.

And the more inputs a neuron receives, the larger its dendrite tree.

So these neurons right here are all Purkinje neurons.

And these are found only in the cerebellum.

And they're one of the most dramatic looking neurons in the brain, they have very large dendrites.

So this is just one cell there, and it has all this large, well I guess there's another one right there, so that's a total of two Purkinje cells.

And each one of these receives about a hundred thousand inputs.

And actually at synaptic inputs, most of those synaptic inputs from these little cells right here.

And these are some of the smallest cells in the brain.

They're called cerebellum mangrove cells.

And these cells actually, are about half of the neuron's [?52:57] in the brain are just that one time cells and they're all found in the cerebellum.

Which is very very interesting but I have no idea what that means.

But they're very small cells and there are a lot of them.

So Purkinje neuron gets inputs from…about, already there are about one thousand inputs from these neurons but I'm not..convinced there's more than one, maybe about ten pluse one from…mangrove cells from Purkinje ones.

But we're not going to study the cerebellum today.

And in the other major difference between neurons is gene expression.

And there's a lot, of course a lot if we set it up fast.

The particular…particularly important differences in gene expression or particular types of genes that differ from one neuron to another, they're called ion channels.

The different neurons has different types of ion channels.

And in the other type of genes that's important that differs between neurons would definitely be neurotransmitters.

So neurotransmitters are, most of the neurotransmitters in the brain they're not exactly, they're not proteins, they're peptides.

So they're not actually coded directly by a gene but they are produced by enzymes and those enzymes are encoded by genes.

So a neuron is, has a, so dopamine in a neurotransmitter will have a specific enzyme that is used just to produce dopamine.

[55:00]

So some of the, as I said one of the main ways of classifying neurons is to follow morphology.

The morphology of the dendrites or [?55:20].

And two of the types of cells that are distinguished particularly in the cortex…[?55:29] are the same, the mid part of the brain along the top is called the cortex.

Or more specifically the cerebral cortex.

So that's the part of the brain that is, most associated with higher functions, higher brain functions and which is most, it's the part of the brain that distinguishes humans from other animals.

And other animals have cortex but the human cortex is much more, including much more of the [?56:06].

So the cortex has stellate cells, it has many different types actually so this is just a [?56:16] example, but one type of neuron is stellate neuron.

Stellate' means 'star-shaped'.

So it just has dendrites going in all directions.

But another major type of neuron is called pyramidal neuron.

And that's shown here.

And it's called the pyramidal neuron because it's shaped something like a pyramid.

So it's kind of pointy up at the top and then the dendrites get a little larger as it goes down and…at the basal, and then the basal dendrites spread out.

And then usually the axon come off, so there is the cell body and the axon comes off down from the cell body.

Neurons can also be classified as spiny or aspiny.

And that's, I have yet anything to say about spine.

And I will talk about that much later in the course when we cover synapses.

But you have, mostly a case, the dendrite of a neuron is clear in a pyramidal neuron, you see little spines so they're very small compared to dendrite as a whole and they are many of them.

Essentially there's one spine for every excitatory synaptic input.

And those spines are specialized for synaptic functions.

But not all neurons have spines, some neurons have no spines.

There's some more examples of more, the morphology

So you classify neurons based on the number of neurites.

The word 'neurite' is just, it's not used that often but it means, it could, it comes from axons or dendrites.

So at some neurons have single neurites…and that would be this neuron in the example so that neuron right there is the type of neuron that I was just describing.

That transmits information from…from the skin to the brain.

So obviously that includes the toe.

And the information from the toe would travel along this axon and it go just right past, right past the cell body.

And there are no…they're not really, there's nothing to call a dendrite coming off that cell body.

So that would be called unipolar because it only has one neurite coming off the cell body.

And then the neuron... something happened, something missing here…

So somewhere else more, well, two or more so, bipolar neuron it's shown in the center and this is major [?59:58].

[60:00]

[?1:00:00] it's never worked and I'm trying to decide if there's something flawed, it's hard to figure out whether I just can't get…the batteries.

So…anyway, bipolar neurons just has two processes.

One coming off in each direction.

And this is…rather, well, it's not the most typical case but there are examples of this in many different parts of the nervous system.

And then multipolar neuron would have more than two neurites and so that in the lower part would be the most typical neuron…most neurons have more than two processes.

So other ways of classifying neurons would be by connections within the Central Nervous System.

It should…

Some of this information comes from, provided in the textbook, [?1:01:07].

And sometimes things get through the [?1:01:13] the CNS refers to the Central Nervous System.

So we're talking about neurons in general, obviously what we're trying to think about, focus on is mainly the Central Nervous System.

But this course is intended to be about neurons in nervous systems [?1:01:31] and so what we're talking about here is not specific to the Central Nervous System.

And as I said, it's actually every neuron has its own unique set of connections.

But in this case, what it's actually mentioned here is referring to rather, a not very specific connection of one neuron to another but just the general, like the general target from which that neuron goes, through the part of the brain it projects through.

So one example of this would be, these are special cases of primary sensory neurons…or motor neurons.

Actually, well no, I get bright on this spot…

So in this case, they're connecting a very true distinction here between the sensory neuron which are actually the sensor receptors in the eye and the skin.

And those neurons are very often very specialized for sensing some particular element of the [?1:02:47].

And then there are motor neurons which are very unique because they project through muscles.

They go directly to the muscles.

And then, so according to this classification, there are three sides to the neurons, there's sensory receptor neurons, there are motor neurons, and then there's everything else.

And then the party of this classification there're 3 types of neurons.

Sensory, receptory neurons, they are motor neurons and there's no anything else.

That's what very prude to station and by...more careful to modify back to by connection within the CNS.

The rest of neurons arranged are usually not called as neurons.

This is statement called ?[1:03:26]   interneurons.

The word interneuron is, it is useful often as meaning is not very precisely default engine.

But it means that neuron that does not projectory forward.

In its case, it senses information that is neurons'd better modified.

So it defines as ?[1:03:51] range union the interneuron ?[1:03:54] outside after…just project ?[1:03:58].

The further classifications are based on their axonal length.

And this is not really normal way to classify the like matrix just like axonal, so that's just not quite…

Some neurons are all projection neurons.

And projection neurons defines simply modified projects for seconds to axonal.

Outside, not the particular ?[1:04:33].

And it's not always clear what state it is in, what the rider is, or in other branch.

So this is not very clear detention.

[65:00]

But this term is used very very ?[1:04:49] and it's generally useful for any projection neurons, neurons projected out within it or ?[1:04:59].

And apparently the higher motors from the progection neurons called Golgi type1 puropose.

And that's very important ?[1:05:14].

But Golgi wasn't ?[1:05:16] discovered for ?[1:5:18] particularly useful type or stage, useful for engeineering for ?[1:05:24] not discovered neurons ?[1:05:29].

And I guess long time ago people distinguish this projection neurons,

from interneuron basically.

So there're both type ?[1:5:46], interneurons, they just project messages that somethings called ?[1:5:51].

So this neurons dispose ?[1:06:00] neurons, interneurons are useful ?[1:06:02].

They don't really state a lot about conversational function of neuron.

And then there's a dispotional ways to classify neurons based on more ?[1:06:21] neurons.

So these are major ?[1:06:33]tional branch.

And then we ?[1:6:39].

There're 2 major ways to…in most of neurons or branch addresses…

And these 2 are deciditory ?[1:06:59] most 20 part.

And then also those other, other more complicated, have rather complex ?[1:07:16] branch.

And another point is one ?[1:07:27] neuron will express 1 type neurons, basic moments of this ?[1:07:35]tional neurons.

There's a little bit ?[1:07:37] about ?[1:07:38] some cases, but that still ?[1:07:42] bonds.

What detention ?[1:07:45] knowing is that ?[1:07:48] one is transmeters.

But function ?[1:07:53]meters also reveal neuropeptides.

And there are a lot of neuropeptides.

And their function often ?[1:08:01] they always…

But neuropeptides are exceptionary steps that impress sessions.

In their any ?[1:08:14] neurons they are not as called transmeters reducer purpose intentional neurons.

So they are all profitable…for example…

And that way about classifying neurons, were we talking a lot more about this phase physiological problems…

So this was anabolic ?[1:8:46] minor channel they express.

And some materials are used ?[1:08:55] example summurogial ?[1:08:59] neurons.

These neurons fire ?[1:09:05].

?[1:09:09] and several ?[1:09:12] stop for a while and ?[1:09:18].

Some neurons are small in adapting if you have ?[1:09:25]tion act neuron, small ?[1:09:28] to ?[1:09:29] respond less.

Other neurons adapt quickly so they respond strong way to ?[1:09:37].

Some neurons have fire ?[1:09:44], fire along simultaneously, which are in neurons ?[1:09:49].

And then they ?[1:09:51].

[70:00]

And then that mean, I mean, ?[1:10:02] classifying neurons particularlly genious expression. And expression that one ?[1:10:10]cal use ?[1:10:12] is a different neurons express wide variety of classifying ?[1:10:18].

More different peptides express those…and there were many other ?[1:10:28]s, genes also very possible neurons.

And already classified ?[1:10:45] to classify for different criteria.

It's also different in ?[1:10:51] neurons.

It's quite certainly unique for something that unique ?[1:10:59].

And there're also examples that precisely not ?[1:11:06].

So certainly it's based on a neuron cortex which recieves they have ?[1:11:17] actions.

?[1:11:21] exactly same values.

And actually ?[1:1:30] neurons…

And in finding ?[1:11:44] we talk about today is neocells.

And I have to much to say about cells and that's about saying about the secret.

By important saying about the ?[1:11:55] about neurons.

The ?[1:12:02] cells most in the decidal cells they are called neo cells.

And fuctional reacts this is the biological text book always said better function of the ?[1:12:16].

This force neurons were just very big, carriage, ?[1:12:26].

Why is certainly, there's a truth of…and there's lot more discovered recently about functional neurons.

There're actually some people ?[1:12:39] very very much more interesting I quite say middle set function.

That is the shown particularly last ten here or so and there's ?[1:12:58].

The tapes there's a lot of ?[1:13:01] between neurons, not that…we have neo state neurons.

And that is sold away inter nodes just what you might be a supportive neurons but by actually ?[1:13:22] in some in neurons ?[1:13:22] information processing, ?[1:13:25].

So many most neurons we have better asterocytes.

And that's just an asterosides shown there.

And I think that asterocytes ?[1:13:52].

?[13:53] asterocytes ?[1:13:56] spaces except neurons.

So it's not a grand look geometry or something by else, someone else to do ?[1:14:06] neurons.

And apparently I did work today ?[1:14:15].

There's a very little space in the brain there's neurons ?[1:14:20].

If you see picture, it's like ?[1:14:26] takes up a lot of space and might think there's not so much there twin neurons.

But in fact that little space are still golgi that fibers are exceled but there're neurons.

But also these asterocytes.

So there's really very little space in the brain, I say space ?[1:14:53].

[75:00]

There's really little ?[1:14:59] of small there outside of fluent.

And that's quite important,

One example of function of the asterocytes is ?[1:15:16] release of one neurons from another point.

It's very important that ?[1:15:20] reaches very ?[1:15:23] concentration.

?[1:15:23] but then these trees take away very very ?[1:15:27].

And obviously ?[1:15:31] diffuse away,

But that distribution ?[1:15:38]s space, the exercise solution.

It is take up by the asterocytes, that asterocytes are very close to syntax, and little transport remain among the asterocytes.

Asterocytes know longer to this effects to the neurons.

?[1:16:04] knows the asterocytes actually ?[1:16:07] a longer ?[1:16:08] neurons go to dead ?[1:16:11] dead bodies.

And then a cyte, neocell is micro glia.

And this function has an asterocytes protecting receptionary cell needs something, so this states a micro neo cells, dead neurons and dead glias.

So it actually cleans up ?[1:16:47] surrenders to it.

I think it also has functions of…of functions….

And then the inside of the cell, myelinating glia cell.

And these are ?[1:17:15] called oliocenderoglia, they're all asterocytes.

And there purple ?[1:17:22] all cells.

And this has very clear and simple functions.

They insolates ?[1:17:33] functions so you can see bottom there from axon neuron that ?[1:17:40] neurons.

And wrap around that axon is all danglocytes.

And it has the membrane of oligodandrocytes just literally wraps around the several times of axons.

So that's show a purple bottom of this picture.

Membrane of oligodandrocytes and that membranes ?[1:18:16].

They have fats actually and integrates insolator.

But that is on ?[1:18:27] neuro fibers.

So this fiber's one in the eye to the brain whole set, calfs or other point brain section.

And you see the black part around each axon is mutiple bags remember brains of oligodandrocyte.

So the function of these neurons insolate ?[1:18:57] neurons ?[1:18:59] fat in the brains.

And insolation sees every invention.

And also releases imparities so much in axons.

And later in ?[1:19:20] fibers and…

I support point of ?[1:19:34] back ?[1:19:36].

So axons which very important information is sended quickly those are ?[1:19:43]ed but the axons are lost and reaching for that in probably from distance to the ?[1:19:53] to half insolation ?[1:19:56].

[80:00]

So you don't need it to be quickly and generally neuro type 1.

So what's next course.

So this axons, back to classic one ?[1:20:29] last one [1:20:31] really nice projector but it also history ?[1:20:37]tion and ?[1:20:41].

?[1:20:46]

So that's what we discovered today, and next time we'll cover chapter 3.

And chapter 3 is very important.

You don't see chapter 3, ?[1:21:05].

Next we will study ion channel discoverage.

And that's saying it's important.

The basic study is ecology and that’s mechanically ?[1:21:27].

And said it came out of neurons.

And samely we weii study ?[1;21:34].

What is important ?[1:21:40].

And they question neuro signs, which will derive to next discovery.

It's ?[1:21:56]

So neurons ?[1:21:1] influence, we knew that was influence actually…understood ?[1:21:8].

?[1:21:17] why the brain message ?[1:22:25].

I just want to why they have particular ?[1:22:29].

So we understand next question.

Understand the basic function, and we got that this are expressable ?[1:22:41].

And I think also ?[1:22:48] express that question.

It's not main purpose, we will definitely talk about snapping plausibility.

How does neuron snap the ?[1:23:5].

Any questions?I have double questions about audiencing that is ?[1:23:34].