GERALD SCHNEIDER: OK. We're just finishing up the introductory lectures before we start discussing neurons in more detail. We've talked about now these three major types of goals of people trying to explain behavior, neurological terms. And I want to say more about the modern subsystems approach today.

And as I mentioned last time, as we go through this, sometimes difficult to keep in mind that neurons are a lot more complex than our little diagrams of reflexes indicate. I want to introduce the use of the subsystems approach. I want to go back to Carl Wernicke and show you how we can put his theory into an information flow diagram.

He was 1874, and this is the picture I showed you before. Let's-- can you see how this is really a reflexological model of speech? Note here that we're speaking a word that you see-- reading in other words, reading aloud-- how is this a reflex model?

Every reflex model starts with a stimulus. What's the stimulus? It's visual. You see the word. OK, he doesn't depict it all the way from the eye here, but he shows here the primary visual cortex.

And he shows information-- so information is reaching the primary visual cortex, the word. OK, now let's just follow it across to the R side, the response side. Visual cortex. And he doesn't-- there may be several synapses there, but when you do information flow diagrams, you're not necessarily concerned with anatomical detail.

Information is flowing to this posterior-- we call it a posterior association area of the neocortex. And then reaches another association area that has been named after Carl Wernicke because it's so critical for understanding speech, Wernicke's area. That information-- information flows from that area to Broca's area. And that connection is well known to neuroanatomists, to the arcuate fasciculus.

OK, so some of these-- all of these arrows here, we can give a neuroanatomical reality to involving various numbers of synapses. Then from Broca's area, the information now has to reach the motor system. And it does that by going to the premotor and motor areas of the cortex.

Information then goes from there to the brain stem and spinal cord and we articulate the word. So that's a reflexological model from stimulus to response. Yes, this is the way that we're simplifying the problem here.

And he's presented here two very simple types of things where you hear a word and speak it or you see a word and speak it. But as you just pointed out, speech is really a lot more complex than that. What else is wrong with this?

Well, that's one of the things that we're going to talk about. What's wrong with the reflex model in general? It is actually a pretty good model and it's helped explain lesion effects when you give this some anatomical reality, as this has tried to do. So let's go a little further with that.

Before we do, we'll just note a few of these problems. That the connections are not always from stimulus to response in the Wernicke model there. There are connections that go from the frontal lobe back to the posterior association areas. This probably is almost as many connections going in that direction as there is in what you could call the forward direction from a reflex point of view.

They also go from sensory cortex not to the motor system, but down to the sensory side, the input side of the spinal cord. We know that the connections can be excitatory and inhibitory. That's often not shown in these information flow diagrams.

They often leave out various modulating influences, diffuse connections, chemicals environment changes. And generally, they don't deal with the possibility that cells can be spontaneously active. They can generate their own activity.

So let's now just draw a reflex in the information flow diagram. I showed it to you at the end of the last class. And then we'll talk about some other things. Simple explanations for motivation and attention and higher control in more general terms.

So here's an information flow diagram, the reflex. Stimulus response with something in between, which we know is the central nervous system. And remember, this concept was already well known to Descartes. He was the first one to describe it accurately, even though his knowledge of anatomy was not so good.

And who was the first one to actually show a connection all the way from the stimulus side to the response side with everything in between? Ramón y Cajal. And he did it with using the Golgi method and he was able to actually to see it and draw it. And I know that some people have not thought the anatomy was even necessary, like Skinner, for example. Question?

The Golgi method is an anatomical method for looking at neurons. You apply a silver solution to the tissue that's been fixed with a particular [? fixidant. ?] And certain cells will take up the silver and become-- when you apply subsequent steps in the method to precipitate the silver, will become totally black.

But the reason the method is useful is it only stains some cells like that, 5% or fewer. And that's why we can see them. If it stained every cell, the whole brain would just be black. So it was a very useful method for looking at neurons.

And Cajal used it to basically establish what we call the neuron doctrine, that neurons are the basic functional element of the nervous system. Well, we can now start to break that model down and add some-- what we know about the kind of processing, information processing that has to be happening. We know that some of the connections don't go directly from the input to the motor apparatus in the spinal cord.

But they go through various kinds of sensory analysis. And in fact, we know-- anatomically, we know these are separate, right? Within the spinal cord. We know that there's sensory analysis in the dorsal horn and lower motor apparatuses in the ventral horn.

If you don't know what I'm talking about, don't worry about it. We're going to see it all very soon. Right now, I just want you to understand the logic. But we're still-- it's still the reflex model. We're still going from stimulus to response. We're just now subdividing the type of information handling that's going on.

So we can make it a little more complicated. We'll keep our direct connections because we know, anatomically, there are such connections. And here's the previous model. And now, we're also going to add additional intermediate circuitry with some connections going back in the other direction.

But it's still basically the same model. We're just adding a little complexity to it based on findings that such circuitry has to exist. We can use such a model to talk about simple behaviors. We know when certain stimuli occur-- stimuli presented to an animal and they reach a certain threshold-- certain responses can be triggered. We call them fixed action patterns, where almost every member of a species will show them if this animal is in the right motivational state.

Every animal, when you present the adequate stimulus and we see it exceed the threshold through neurons we sometimes called command neurons-- we will get fixed action patterns. We call these movements instinctive movements. We have them too.

It doesn't say that they're not plastic. We know from since the time of Pavlov that such circuits are subject to change. Sometimes we call that shaping by the environment. It's also a term used in training of animals.

So now let's ask, well, what more-- when we have a brain and not just a spinal cord and brain stem, what more does the brain do? Let's show the concept of higher reflex arcs, which was a way to talk about brain function and still preserve the reflexological model. And this was the model used in Russia at the time of Pavlov. And it became sort of almost a political doctrine in the old Soviet Union.

I went to a meeting in the late '60s in Moscow when I was-- I won some prize as a young neuroscientist and went to Moscow. And I found out that every time a Russian gave a talk, he had to talk about Pavlov and the reflex model. It was required.

They would laugh about it behind the scenes, but it was required because there were people there watching them. And that was politically necessary. So we'll talk about that, first of all. And then I'll talk about gating mechanisms and if we have time, a little bit about evolution of higher control.

So this was the idea of a hierarchy of reflexes. This would be the lower level spinal cord. Then we know sensory input passes up to brain stem, even up to the far brain. But we can-- and sensory inputs also come in at different levels.

In every case, to affect a movement, you have to reach the motor apparatus connected to the spinal cord, if we're talking about limb movements at least. So every one of these somehow had to come down to the response site. So this is just a simple way to depict a reflex hierarchy and extend the reflexological model to higher function.

OK, let's talk a little bit about gating mechanisms. We can imagine this-- here's our reflex model that we showed you before. Now, let's imagine some mechanism in the brain that is influenced perhaps by motivational states or perhaps by something else.

And it simply alters thresholds in these boxes. It can excite them or can inhibit them. It serves as a gate. It can block information coming through here or it can enhance it. That would be a gating mechanism.

And that could account-- be a reflex. You could still keep to the reflex model. If you add this, you can account for attention. You can also account for motivation by a very similar kind of connection.

If this inputs here, say, a responding to the state of the blood and indicating energy levels. When this reaches a certain point, it corresponds to hunger. What does it do? It enhances reflexes involved with searching for food, opening of the jaw, and so forth.

And it's actually a very good model to account for, say, the hunger of a human infant nursing. Very simple changes in threshold of the rooting reflex and the suckling reflex are what occur. OK, now I'm just going to present you a way to think about higher control that complicates this whole thing.

Some of you will have a little trouble understanding my logic here. And I'm sorry I had to make this so small. I did it with PowerPoint so this should be huge up here because this corresponds to forebrain. And here's our reflex circuit.

And now, I've divided the information flow into slightly different models. I go through a sensory analyzer here. And here's the motor apparatus. And in between, I'm showing a mechanism that's acting as a comparator.

It's comparing the inputs coming in here with something coming down from the brain. Now, what's coming down? Remember, I'm talking about the logic of the system, not about necessarily actual connections, though we know there are this type of connection.

This represents the two major kinds of functions of the neocortex in higher animals. Formation of images and of plans. You can think of the entire posterior neocortex is involved in images.

That's where the sensory inputs come in, auditory, somatosensory, visual, primarily. And we form images. We form visual memories. And it's those visual memories I'm particularly interested because they represent images of the world around us.

If I shut my eyes here, I can still walk around. I actually can still see you. I don't know if all of you can do that, but I have a visual persistence phenomenon so I can continue to see something.

And I step here and I know there's somebody right there, but not here because I could remember it. And how am I doing that? I'd like to give you all a test to see how many of you have that function because we're studying it. But I'll try to remember to do that the next few classes. That involves the posterior neocortex.

Then you could call it a model of the world that we all have. How do you know you have to have such a model? Well, think of your dreams. Where's that coming from? It's coming from your nervous system and your memory.

And yet, there's a whole world in there, right? In some cases, it can be so vivid and so accurate that you can't even distinguish it from reality. If any of you have had Hypnagogic Imagery, which I've had a few times, I've literally had to pinch myself, try to wake myself up because I couldn't distinguish-- I couldn't tell for sure if this was real or not.

So these models that we have are extremely well-formed. And they represent the world around us, but it's all from memory. We always-- when we're looking around, we expect certain things. These are sometimes called expectancies, these models.

The frontal cortex is involved with movement and planning for movement. The motor cortex controls the movement premotor cortex plans and executes through the motor cortex and more complex movement. In front of that, you simply have plans of a more distant sort, including areas that if you don't have, you'll never buy an insurance policy because you won't anticipate the future at all.

Images and plans-- now, let's look at the model. Here's what this suggests. If the model is anticipating the input that's going to come in, it would block the reflex and control the movement through the forebrain. If we don't anticipate it, there will be a mismatch here, two things will happen.

The reflex will occur and we will disturb the forebrain and alter it. So it alters the images and plans. That's all this shows. There is direct evidence for that kind of thing. I can describe some of it from my animal work.

But when you think about it, all it does is describe what we know psychologically what's happening. Now, there's a talk here coming up. I think it's-- I don't know if it's this Friday or next Friday. Woman talking about perception as an anticipation of natural scenes. She's going to present evidence of this sort. She's a psychologist.

But this is giving that kind of notion, putting it into an engineering-type model. Let's just give a brief introduction too. You don't have the print out for this, but this will be the next class. I guess I had already opened it.

This is what we're going to be doing now in the next few classes. First, we'll be talking about what I call primitive cellular mechanisms. They're mechanisms expressed in the properties of single neurons. Single cells, in fact, even single-celled organisms. And we're going to show how those are expressed in neurons.

So we'll basically be doing properties of neurons and their membranes. And the specializations of nerve cells. When we finished that, I'll say some things about evolution of multicellular organisms. These are ideas of others and mine that are based on comparing many different species of animals.

And then I will introduce you to neuroanatomy more generally. Give you a schematic outline of major connections in vertebrate brains. These are the mechanisms we'll be talking about now in the next class.

Irritability and conduction. Irritability means the cell is responding by changing when there's some input to it. Like, if you tweak and amoeba, what does it do? Well, if you tweak it hard, it shrivels up and pulls back. If you do it very lightly, it responds in a different way.

The membrane is irritable and responds to input from the outside. So the amoeba can flow around something and ingest it or it can pull away. That's because it's an irritable cell. It responds.

Not only that, the membrane doesn't just respond locally, but that response affects the whole cell. So it has to be conducted to other parts of the cell. So that happens in single-celled organisms. And the neuron is particularly specialized for conduction. And we'll talk about that.

We'll say a little bit about movement, not too much, and secretion, a major function of cells and neurons, in particular, and other cells in the body. And then the various specializations of the membrane for irritability, the sensory transduction mechanisms. And then we'll say more about endogenous activity, which we've mentioned before. OK?

Most of the things on movement I will defer until we talk about development. So after I talk about evolution and give you an outline of the vertebrate brain, then we will talk about development of the nervous system. OK? So let's start here with the next class.