Hello. In this lecture, we will discuss how the brain supports cognition. The big idea in this lecture is that normal everyday craziness that we experience begins at the very first stages of information processing in the brain.

So let's start at the beginning and discuss how neurons work. But if you're like me, your initial response is, who cares how neurons work? However, it turns out that this is a really interesting question, and it's critical for answering one of the most important questions in all of science.

What is that question, you ask? The key question concerns the relationships between the brain, the mind, and behavior. Indeed, at the turn of the new millennium, scientists voted this to be the second most important question, following only the origin of the universe.

As cognitive psychologists, we have historically been primarily interested in the second half of this question--specifically, we have been focused for the past 60 years or so on figuring out the nature of the mind by observing behavior. However, during that time, neuroscientists have discovered many important things about how the brain works.

In fact, theories derived from cognitive research often predicted the discoveries made by neuroscientists. That relationship has now become a two-way street. Theories of the brain often informed theories of the mind and vise versa. This is what we call interdisciplinary approach to understanding.

In fact, many of the hottest new ideas about the relationship between the mind and the brain come from other fields, such as artificial intelligence and statistics. This interdisciplinary field is known as cognitive science. Thus our understanding of the brain constrains our models of the mind, and our understanding of behavior constrains our models of the brain. And since brains function as a result of the interactions of billions of neurons, it's important to understand how neurons work. From the perspective of cognitive psychologists, neurons are cells that receive and transmit information.

The figure at the top shows a typical neuron. Notice that the neuron consists of several different parts. The smaller spiky areas of the neuron are called dendrites. These receive information from other neurons. The longer projection of the neuron are called axons, and these transmit information to other neurons. The information transmitted between neurons is in the form of electrochemical energy. They're actually like little circuits.

The neuron on the bottom is a special type of neuron called the sensory neuron. It does not receive information from the axon of another neuron, but from the environment. Thus the form of this information is different. It is in the form of physical energy. For instance, let us assume that it is a sensory receptor associated with vision.

Photons of light landing on the receptors of the eye stimulate this receptor. Sensory receptors convert this physical energy to electrical energy.

So here is one of the big ideas-- from the very first stage of information processing, our brain is transforming our environment into a representation of it, and this representation is the result of translating a physical stimulus into an electrochemical representation of it. This process is known as transduction. There are many sensory receptors associated with all five senses.

So one question we might ask is how neurons respond to changes in the environment or other stimuli. One way to address this question is to take recordings of the activity of single cells. The goal is to detect the signals produced by a single neuron.

These signals are known as action potentials. The form of the action potential is a change in the electric chemical charge of the neuron. When such a change occurs, the neuron is said to fire. In its normal state, the inside of the axon is negatively charged.

When one patch of cell membrane is depolarized enough to open its voltage-gated sodium channels, positively charged sodium ions enter the cell. Once inside, sodium ions nudge adjacent ions down the axon and attract negative ions away from the adjacent membrane. Once the adjacent patch of membrane is depolarized, the voltage-gated sodium channels in that patch open, regenerating the cycle.

The process repeats itself down the length of the axon. As a result, a wave of positivity moves down the axon without any ion moving very far. This is known as propagation.

To make individual cell recordings, an oscilloscope is used. What this diagram shows is that it takes about one millisecond for a neuron to go from negatively charged to positively charged and back. In other words, it takes about one millisecond for a neuron to fire. This is referred to as an action potential.

This diagram also shows that a neuron may actually fire many times in response to a stimulus. The greater a stimulus activates a neuron, the more time it fires. This is known as its firing rate. Note each action potential is of the same magnitude. Hence, the firing rate-- not its magnitude-- is a measure of how active a neuron is.

This slide shows what happens when two neurons meet. Actually, they do not physically meet. But something occurs in the gap between the axon of one neuron and the dendrite of another neuron. This gap is called the synapse.

Messages are sent in the form of a release of neurotransmitters into the synapse. There are two types of messages that can be conveyed from one neuron to another. The message can be excitatory, in which case the sending neuron is encouraging the receiving neuron to fire. Or the message could be inhibitory, in which case the sending neuron is discouraging the receiving neuron to fire. The firing rate is determined by the difference in the amount of excitatory versus inhibitory neurotransmitters that are released.

This slide shows how this difference is computed. Here we have two different scenarios. In both scenarios, we have two neurons synapsing on neuron A, five neurons synapsing on neuron B, and two neurons synapsing on neuron C. Two of the synapses on neuron B come from neurons A and C.

In the top scenario, all synapses on B are excitatory. Whereas in the bottom scenario, the synapses from A and C are inhibitory. The figures on the right plot the firing rate of B as a function of which receptors are activated.

In the top scenario, the synapses are excitatory-- so the more receptors that are activated, the greater the firing rate of B. In the bottom scenario, when receptors synapsing on A and C are activated, the firing rate of B is depressed.

True or false? Studying the workings of neurons helps us understand the relationship between the brain and mind. The answer is true.

True or false? Typical neurons send to and receive information from each other. The answer is true.

True or false? Transduction is a transfer of information from one neuron to another. The answer is false. Transduction is a conversion of one form of energy into another form of energy.

True or false? Neural activity is measured by the magnitude of its firing. The answer is false. Neural activity is measured by the rate of firing, not the magnitude.

True or false? The combination of excitatory and inhibitory neurotransmitters released into the synapse determines the level of firing in the receiving neuron. The answer is true.