Okay, so now we are going to talk about neurophysiology.

In the body, electrical currents correspond to the flow of ions across cellular membranes. The transmission of a nerve impulse is very similar to the process of a muscle contraction that you learned about previously, and occurs in the following steps.

We have a resting membrane potential, where the cell membrane is considered to be polarized. We have a depolarization and the production of a graded potential. Then, there is a conversion of the graded potential to an action potential, and then the propagation of an action potential – down the length of the axon to the synaptic terminals.

Next repolarization or re-establishing the resting membrane conditions occurs. Ion channels play a crucial role in establishing ion concentrations on either side of the neuron cell membrane and they can be classified in the following ways.

Passive or leaky channels are protein channels that are always open, allowing certain ions to pass through. These channels are responsible for maintaining the resting membrane potential and are located all over the surface of a neuron.

Active or gated channels are protein channels that open and close in response to various signals.

Chemically-gated ion channels open when the appropriate neurotransmitter or chemical binds to the receptor site on the protein. These are important for depolarization and the production of the graded potential and are located only on the dendrites and cell body of the neuron.

Voltage-gated ion channels open in response to changes in the membrane potential. These are important in the generation and propagation of an action potential and are located only on the axon.

Mechanically-gated ion channels open in response to some physical deformation of the membrane surface caused by exposure to touch, pressure, or vibration – and remember, ions are moving down an electrical chemical gradient.

Here you can see some examples of cell-to-cell membrane and transmembrane proteins, which make up the different types of channels that we just discussed.

Here is an example of a ligand-gated channel – or chemically-gated channel, where a neurotransmitter or chemical binds to its appropriate receptor site on the protein, which opens the channel.

Mechanically-gated channels open in response to some physical deformation of the membrane surface, which again can be caused by touch, pressure, or vibration – and voltage-gated channels, which open in response to changes in the membranes potential.

Leaky channels – remember – are always open and they allow for only certain ions to pass through.
And again, certain channels are located on the axon of the nerve and other channels are located on the dendrites and cell body – like the chemically-gated ion channels versus the voltage-gated ion channels, which are located on the axon.

The resting membrane potential is referring to when the cell membrane is polarized. The resting membrane potential exists only across the membrane – that is, there is a bulk of solutions inside and outside the cell that are electrically neutral.

The resting membrane potential in neurons is approximately minus 70 millivolts. The inside of the neuron's membrane is negatively charged, while the outside of the neuron's membrane is positively charged.

Sodium is in its highest concentration outside the cell, while potassium is in its highest concentration inside the cell. All voltage-gated, sodium, and potassium ion channels are closed so that the neuron cell membrane is relatively impermeable to the two ions. Passive gates for both ions remain open, but movement is minimal.

And here, we could measure the resting membrane potential using a voltmeter to see the distribution of charge across the cell membrane.

Now graded potentials are processes and can sum to produce an action potential. When we have a neurotransmitter within the synaptic cleft and it opens sodium chemically-gated channels and sodium begins to rush into the neuron down its concentration gradient, this process can begin the formation of a graded potential and hence depolarization of the membrane. In that local area of the membrane, the interior side of the membrane begins to change from a negative charge to a more positive charge – while the exterior changes from a positive to a negative charge.

Any change from that resting membrane potential of minus 70 millivolts is called depolarization. As depolarization occurs, the membrane potential becomes less negative – moving from minus 70 millivolts towards, for example, minus 60 millivolts. This switch in charge begins to spread across the dendrites and cell body and is now called the graded potential.

If the threshold is great enough, an action potential may ensue – and here you can see some of the steps we just talked about. The chemical stimulus opens the sodium channels and as sodium channels are opened we go through a depolarization phase. During the repolarization phase, sodium channels are closing and potassium channels are opening.

Graded potentials do show some differences between action potentials. Graded potentials have what we call a detrimental conduction, which means – you can see here in this bottom figure – the strength of the stimulus decays as it gets farther and farther away from the origin of the stimulus. Graded potentials also can go in both directions, whereas action potentials only go in one direction.

Now action potentials can occur as a result of graded potentials. If the graded potential reaches the axon hillock, the voltage-gated channels within the axon hillock open – which causes the sodium ions to flow into the axon, switching the charge across the axolemma. This causes the voltage channels to start opening all the way down the axon and the action potential now moves
down the length of the axon. This is called the propagation of the action potential and can generate a change in the charge from that minus 60 millivolts to positive 30 millivolts.

Once generated, an action potential cannot be stopped. This is referred to as the all-or-none principle. Myelin on the myelinated nerves causes the local depolarization to jump to the next node of Ranvier and then from node to node. This type of propagation that occurs in myelinated axons is called saltatory conduction and is a very rapid form of signaling.

On unmyelinated nerves, local depolarization must spread to sites immediately adjacent to each other, creating a continuous conduction pattern. This type of propagation is relatively slow.

And here you can see the phases of an action potential. Hyperpolarization can sometimes occur because potassium channels are slow to close. So the membrane potential can actually go below minus 70 millivolts.

Now during the repolarization phase of an action potential, the removal of the neurotransmitter from the synaptic cleft causes the sodium channels to close so that no additional sodium enters the cell – and that's what's occurring in step 4 here of the figure. The rapid outflow reduces the total number of positive charges within the cell, causing the charge to switch back across the membrane from positive 30 millivolts to minus 70 millivolts. The membrane now goes back to positive outside and negative inside – and again, because the potassium channels can stay open longer, the membrane may become hyper-polarized – which is shown here in step 5 – and that would be, let's say, approximately minus 90 millivolts.

At this point, the sodium potassium pump is signaled on and pumps 3 sodium ions to the outside for every 2 potassium ions pumped to the inside. This reestablishes the resting location of ions, while also reestablishing the resting membrane potential of minus 70 millivolts – and that's step 6 here in the figure – where the membrane potential has returned to its resting state.