>> March 9, 2015, our first lecture in this new unit, neuromuscular physiology. Really an incredible system which makes possible so much of the joy and pleasure associated with our life and certainly it's not an oversimplification to say that you are your nervous system. If you think about it, the rest of our body is just plumbing and motors, but what makes you different from anybody else or any other animal is your nervous system. So, an appreciation of that is understood from the get-go. On the day of your birthday, your brain contained at least a hundred billion neurons and at the time of your death, let's say you live to 80, you still have 99 billion neurons. So as adults, we lose neurons, but we don't necessarily lose functionality. In fact as adults, you have fewer neurons than when you were born. What you have way more of are synapses and we'll learn that those are what make you different, more intelligent, or otherwise a different human being from somebody else. And the nervous system is highly dependent on your genome, remember those 20,000 genes, very many. Most of those are designed for and used in the development of the nervous system. So, it's incredibly complex, incredibly tied to the genome in terms of its ability to be developed and function properly. So, with all that said, let's start out with a simple statement. The nervous system is really designed to generate, that means to create, to transmit and to integrate, that means make sense of what we'll call, at least for now, electrical signals. And these make possible sensory function, that is awareness of everything around us, as well as motor capacity, the ability to speak, the ability to take notes, the ability to walk or even breathe. So, this is a very simple sentence, but it encompasses at least most of what the nervous system does for you. Remember, the nervous system is made of fundamental units called neurons. And you can call a neuron a nerve fiber, a nerve cell, and it's all the same. And so, these are the functional units of the nervous system. The interesting thing here is there are only three basic types of neurons in the entire nervous system and these are already familiar to you. First, so called sensory nerves. Sensory nerves are those that carry information, signals about the internal or external environment into your spinal cord, eventually to your brain for processing and interpretation as some sort of event, some sort of sensory stimulus. Sensory nerves are also called afferent, you might remember that word. Afferent means to travel in so these are the fibers that carry information into the spinal cord and up the cord, eventually to the brain. These sensory nerves originate in the periphery, that is they originate throughout your body usually in association with other cells called receptors. Receptors for sight, receptors for sound and so forth. So, sensory nerves carry information generated by receptor cells. This information enters the spinal cord, eventually arriving in the brain and you have some response that is some interpretation of whatever sensory event that might have occurred. Here's a typical sketch of a sensory nerve. This is the cell body, and you might recall from anatomy that neurons typically have long, radiating processes, some are shorter, some are longer. And perhaps you recall that those components that carry signals toward the cell body are called dendrites and those processes which carry the signal away from the cell body, their name is axon. So, here to review, we see a typical nerve cell body and this long radiating process identified here is an axon which can be in many cases quite lengthy. So, here are the three types of neurons that we're about to review and we've just finished with the first of the three namely sensory nerves. What's the opposite of a sensory nerve, that is what type of nerve carries signals from the brain down to the spinal cord and eventually out to some distant or peripheral location? That's a motor nerve. And why is it called a motor nerve? Because something in the way of movement will happen in response to their activity. The other name for a motor nerve is efferent. If afferent means to travel toward then efferent means to travel away from, in this case, away from the spinal cord, out to some muscle. So motor nerves carry signals that ultimately produce movement and that means their target or destination is typically skeletal muscle. So, here's an illustration of a motor nerve. Very often, they have cell bodies that are multipolar, you might recall that. And as such, they have very short highly-branched dendrites and one very long, very straight single axon. So, this is the typical anatomical or structural look to a motor nerve. But where do motor nerves originate? In the brain and they travel or carry their signals down the spinal cord and eventually to some sort of muscle, more often than not, skeletal muscle but also sometimes a gland bringing about some secretion or some action of that gland. We said there were three, so what's the third? The third type of impulse generating neuron are those that are called interneurons which is almost self-explanatory. Inter as a prefix means between, so these are those neurons that lie between or otherwise connect a variety of neurons in the brain and spinal cord. And notice that interneurons are not found anywhere except the brain and spinal cord so their job is to link synaptically neurons in the brain and spinal cord and they bring about or enable very complex sensory interpretation and also the execution of very complex behavior or movements. If we put numbers on the board here, it's an interesting comparison because in the brain, for every sensory nerve, there are about 10 motor nerves and probably 10,000 interneurons. So, with that said, what is most of your brain made off? Not sensory, not motor, but far in the way the interneurons. And that explains why our brain is so big compared to let's say, a hamster's brain. No, I'm not saying that a hamster's brain should be as big as ours, but at least size wise, we have a very large brain and its size is mainly due to the complexity, that's your numbers of interneurons. And therefore, we have what capacity that hamsters don't? Do we

have the capacity for a higher intellectual thinking, philosophy, music appreciation? I don't think hamsters are doing calculus in their spare time. And so, why are we at the high end of the neurological spectrum? It's not because of our sensory nerves, it's not because of our motor nerves, it's because of our interneurons. And so, they give us this capacity for a higher intellectual functioning and also the execution of very complex behavior, whether you're thinking of dance or gymnastics or something where the performance of the human body is clearly superior to any other organism on the planet. Interneurons are also called association neurons because they allow us to make associations, that is to take this information and interpret it to make sense. What does it mean now in this context for the moments that we are experiencing? Interneurons then are highly complex networks within the spinal cord and brain. And by networks, when we say linking neurons, we mean linking them through functional connections that you know by a name called synapses. A synapse is not a physical connection, but a functional connection between any two neurons typically inside the central nervous system. And we gave you this figure that in your brain at birth, there are a hundred billion neurons, right? And if each neuron is capable of forming about 10,000 synapses, then do that math, a hundred billion times 10,000, we're talking about a thousand trillion synapses in the human brain at least in adulthood. Are you capable of doing things, reasoning and executing things that you couldn't when you were young? It's not because you have more neurons, it's because you have more S-word, synapses. And do college graduates have more synapses than high school graduates? Yes. More than high school dropouts? Way more. And so, are you in fact building synapses this very moment? Yes. And so, our intellectual capacity is a function not of the number of the neurons that we have. Einstein's brain didn't have any more neurons than yours, but certainly compared to mine, it had way more synapses and therefore capable of thinking way outside of the box so to speak. So, what makes a nervous system superior is not just your number, but rather the number of connections, i.e. synapses, which leads us now to a more proper description of these nerve junctions. Synapses by definition are not physical connections, but functional points of communication between neurons, typically in the central nervous system. So, functional connections between two neurons and these allow, what's the statement here? Allow for what? Enhancement or what? Reduction in nerve-to-nerve communication. So, it might be tempting to think of a synapse as a switch, but a switch is either what? On or off, but these are more like valves. What's the difference between a valve and a switch? Well, a valve can be metered up or metered down and so synapses allow for the, what's the word here? Enhancement or also the reduction in nerve-to-nerve communication. And this statement is vague perhaps right now, but we'll come to appreciate that the condition, not just the number, but the condition of your synapses has a lot to do with your mental status. Are there many mental or neurological diseases that are the result of synoptic failure? And the answer is yes. If you think about things like schizophrenia or bipolar disease, it really boils down not to a failure of the nerve, but some failure in the nerve synapses, which we're only beginning to understand. So, synapses allow for enhancement and reduction of communication between neurons in the central nervous system. Outside this central nervous system of course, we have synapses which are different, synapses between motor nerves and muscles and for that reason, they're called something else. They're called neuromuscular junctions because that's exactly what they are, connections, functional connections between motor nerves and skeletal muscle cells. If these fail, what's going to be the consequence? If your neuromuscular junction fails, what's not going to happen? You won't move, and by any other name that's paralysis, by any other name that's death. And so, the integrity of your neuromuscular junctions are critical. This is an actual photo of many synapses inside the brain. Here's your typical diagram of a synapse, only to emphasize that a synapse is not a physical connection, but a functional connection because a synapse actually is a gap or an area between two neurons which allows for communication by the release of neurotransmitters through that process we've already discussed called exocytosis and through the release of synaptic vesicles. So, to reiterate, mental status, mental health, often boils down to not the number of synapses, certainly not the number of neurons, but the functionality of your synapses. Are your synapses performing as they should? And if not, perhaps we can intervene with drugs or therapy to improve their normal performance. So, as we leave this section, synapses are between nerves and neuromuscular junction is between a motor nerve and a muscle cell. But from an anatomical standpoint, this might be a synapse, this is a neuromuscular junction. We'll come to find out that their physiology, that is the way they work is very similar and even their anatomy is very similar, the only difference is the consequence. Neuromuscular junctions lead to movement, synapses lead to interpretation and behavioral changes within the central nervous system itself. So, next in the rundown of neurological review are so called nerve coverings. Nerve coverings are made up of totally different cells that are not impulse generating. In fact, if you recall the name neuroglia from anatomy, I hope, and there are many types of neuroglia, but basically these are cells that literally wrap like tape around a pencil, literally wrap themselves around axons, sometimes also dendrites. And remember, what are cell membranes made of? Cell membranes are made of phospholipids. So, essentially these cells are layer upon layer upon layer of phospholipids creating a thick coating which you know by the name myelin, not to be confused with that brown pigment in your skin. What's that brown pigment in your skin? That's melanin. This is myelin which provides insulation to the axons, not unlike the insulation of any electronic cord that you might have. Does this cord that's leading to the outlet on the wall contain some wires? But are those wires insulated from each other with some sort of covering? Yes. So, myelin provides that same electrical insulin and right away, you would appreciate the disease called the demyelinating disease. What does that mean? To demyelinate would be to strip off the myelin and now these axons would be free to touch physically creating a lot of short circuiting, a lot of information that would jump or otherwise haphazardly move among neurons. So, the function of myelin is to keep signals on track and also to improve the speed of propagation, the speed at which these signals travel. And incidentally, it's a very impressive velocity. How long do you think it takes a signal to go from your toe up to your brain? Actually, less than 0.02 seconds and that's on the order of 200 miles an hour. So, this is made possible by the velocity-improving role of the myelin. And here's an actual look at some axons seen here in purple. So, this covering must be the M-word, what's that? Myelin, the myelin sheath. There are many demyelinating diseases, the most common that--I'm sure you know of is MS. What's that stand for? Multiple sclerosis, this attacks neurons throughout the spinal cord and brain. A less well known but nevertheless a demyelinating disease is called amyotrophic lateral sclerosis, also known as ALS. There's a movie out now that actually received quite a bit of attention, all about Stephen Hawking, what's the name of it? Nobody saw it, all right. That was actually a wonderful movie and a very renowned physicist who had and contracted ALS in youth and defied all the odds because the usual life expectancy of anybody with ALS is about two years max and he has survived, now into his 70s. So, a fascinating individual, a wonderful movie to see and appreciate, not just for his accomplishments but his wife's contribution, so go see that movie. Anyway, myelin, myelin is formed in the peripheral nerves by cells called Schwann cells, and Schwann cells are essentially duplicated. That is their function is assumed in the central nervous system by a different kind of glial cell called an oligodendrocyte. Now, both of these are compared side by side. A Schwann cell is more or less like a pancake that's been folded or wrapped around an axon and there are multiple Schwann cells necessary and interrupted along the length of a typical axon. What makes an oligodendrocyte different is that a single oligodendrocyte will reach out and wrap itself around multiple axons. But aside from that, we still have the very thick and important phospholipid layering which creates the myelin. And also as you know from anatomy, these myelinated cells are not continuous, but actually interrupted, that is there are gaps here, remember that? And the name of these naked or gaps, these naked spots along the axon are called nodes or nodes of Ranvier. These are not just curiosities because only here at these gaps do we have channels, ion channels, for the passage of sodium and potassium. And so, these nodes are extremely important as the site, the location, for the creation and the propagation of electrical signals, and in fact it's the spacing of these nodes that allows signals to run so quickly, that is so fast along axons, nodes of Ranvier. So, just backing up a bit, glia, glia can form myelin, one of the two myelin-creating cells, we have what? Schwann cells, only found in nerves outside the central nervous system. Oligodendrocytes are only found in the brain and spinal cord. Essentially though, they both contribute to--that is cause the formation of a myelin sheath. Next, we want to realize and take you back to anatomy because certainly there you learned about various nerves by name. Remember olfactory nerve, trigeminal nerve, sciatic nerve, phrenic nerve, all of these are nerve bundles, also called nerve trunks which are literally cables, literally aggregates of thousands and in some case millions of axons which are traveling within the peripheral parts of the body, that is up and down the arm or leg or whatever. So, a nerve trunk is described as a cable-like grouping of mixed nerves. And here's a diagram that might be familiar showing a nerve trunk. You might even remember some of these terms. What's the name of that envelope that wraps the whole burrito? That's the epineurium. Then inside, we have the--there it is again? Perineurium. And even deeper, we have the connected tissue between axons called the endoneurium. The point that I'm making here is that when we describe a nerve like the sciatic nerve, it's not a single cell by any means. Tens of thousands of nerves, some of which are S, some of which are what? Sensory, some of which are motor, so it's a two-way lane, a two-way highway, signals going in, signals coming out of the central nervous system. One type of nerve fiber that you won't find in nerve bundles though is what? Yes, there's sensory, yes, there's motor, but there's no what? No interneurons. Those are only found in the brain and spinal cord so a typical diagram then of a nerve bundle or nerve trunk. And each of these individual nerve cells which is barely perceived here in this diagram, each one is surrounded by myelin, of course, and then surrounded externally by the endoneurium, perineurium, epineurium. The point is, this is very well designed to protect and maintain the flexibility and functionality of these individual cells. All right. So now, a breakdown, that is an organizational discussion of the nervous system that I'm sure you're already familiar with. In fact, we've already thrown out some terms, some acronyms at least. What was PNF? Peripheral nervous systems. CNS? Central nervous system. Now, let's be clear, these are not separate. That is they're just different regions of our nervous system. We only have one nervous system. Many of these components are central, many are peripheral, they all work together to bring about every thing that we're capable of doing. So, just as an organizational map, let's break this down starting with the CNS. And what are the two components of the central nervous system? First, you might begin with--we should begin with the spinal cord which is well protected in and found along the vertebral column or the spinal canal. So, you recognize the vertebrae and the bone that protects the spinal cord off course. And not only as the spinal cord protected by bone, it's also protected by tough connective tissue membranes, right? And so, I'm taxing your recall here, but you recall the M-word, the meninges. Yes, and maybe even the dura mater, the arachnoid and the pia mater. All of these are designed to physically protect and isolate from infection of the spinal cord, not withstanding all of these protection is the spinal cord subject to injury. Can it be destroyed or severed in that? It only takes a bullet to go across here or some sort of shrapnel to render somebody paralyzed for the rest of their lives. So, even though it's well in-cased, it's not without sensitivity to trauma, needless to say. The amazing thing about the spinal cord is that in most locations, its diameter is no greater than your little finger, but in that space, there are 20 million axons going north and south. Twenty what? Million and so it's a very busy highway going north and south. And those fibers that are indeed going north are called ascending tracts, ascending because they carry signals up to your brain. And therefore, obviously, what sorts of nerves are found in ascending tracts. Well, they're sensory nerves. The signals that they carry are going to register ultimately as some sort of sensation, oh, that's hot, oh, that's cold, something like that. So, ascending tracts originate in the periphery. That is this information comes from, let's say an arm or hand, and travels up the cord in this so called ascending tracts. With that said, what would be the clinical manifestation? What would be the patient's complaint if these ascending tracts were selectively destroyed? Selectively, meaning by themselves. If you cut, injure or demyelinate an ascending tract, what's not going to get to the brain? And so, what is the name for lack of sensation? There it is, anesthesia. Now, most f us think of that word, anesthesia, as something that happens to you in the operating room that is you're given anesthesia. But the word is simple, anesthesia means without sensation. And so, any interruption in ascending tracts will cause anesthesia, not unconsciousness, but just the lack of sensation. So, anesthesia is the consequence, by any other name, you might call it numbness. Ever heard that? Ever used the word numbness? Maybe when you had dental work, you know, you're given what? A local anesthetic. And you say, "Oh, my mouth is just numb," N-U-M-B, all right. But it's actually what? It's actually under some degree of anesthesia. Now, what do we call these southbound highways? The southbound highways are coming down from the brain, and as such, are ultimately going to arrive at some distant to a peripheral location. And so, these obviously are motor nerves, and their destination is skeletal muscle, skeletal muscle in the hand, foot, wherever. And therefore if you damaged descending tracts, the result is fairly predictable. They're going to have the P word absolutely, it's called paralysis. It doesn't have to be total paralysis, it could be partial. And partial paralysis is otherwise known as weakness, that is muscle weakness. But certainly, total paralysis is not uncommon. Indeed, when we speak of the spinal cord and when we speak of injury to it, is trauma selective for or likely to affect just ascending tracts? So trauma to the spinal cord is very indiscriminate. It's going to destroy ascending and descending, at least to some degree. So anybody with spinal cord injury has a great deal of what? And a great of? Whether ether it's total, we don't know because there are degrees of spinal cord injury. Certainly, if the spinal cord was totally cut, is that possible? Yeah. If it's totally cut, then you have no sensation below that injury and you have no movement below that injury. In other words, you have total anesthesia below that point and total paralysis below that point. So, obviously, spinal cord injuries are devastating and worse than that, they're permanent. That is there is no way currently to restore functionality to any great degree especially in a complete transaction of the spinal cord. So, there are certainly celebrated people who have crusaded for spinal cord research, maybe the one that rings a bell is Christopher Reeve who indeed established an institute at Irvine for spinal cord research. You might recall he was paralyzed from the neck down as a result of a simple fall from a horse. And prior that, he was a very celebrated movie star in the early superman movies, you might recall. So, I'm just trying to make clear how valuable our spinal cord is even though we think of it as just a highway, it is our link, our link between the brain and our peripheral muscles, as well as bringing to us information about everything in our body and outside our body so it's hard to dismiss it. It's very important. But of course, the brain. How can you say-- What will we'll be able to say in 20 minutes about the brain? Very little, except to organize it for you and review some of its basic components as you might already know. So, what about the brain? I supposed, you recall, that the brain can be divided into three regions somewhat arbitrarily. And most of what we visualize as a human brain is wrapped up in the so-called forebrain. Then between the forebrain and hindbrain, there's the midbrain. So those are the three regions we're going to review with clear attention to what dominates the human brain and that is the forebrain. The forebrain is dominated by the cerebrum. And you recall that, that has two identical hemispheres, right? The one in the left is called the left hemisphere and the one in the right, the right hemisphere. For all accounts, these look pretty similar, that is they appear to be mirror images of each other. But this is a standard view of the left hemisphere, the right one appears to be the same, very different in terms of what's going on there but at least, we could say certainly, you have two cerebral hemispheres. And you might recall the names of some of those sulci or gyri here. At the very least, you know that this is the frontal lobe, this is the temporal lobe, this is the parietal lobe, and back here is the occipital lobe. So those are landmarks or anatomical names that you recall. And what goes on in the cerebrum? Well first, sensory what?

Interpretation. What does it mean? That is what does that sensation mean to me? Not just what it is, but what should I do about it? Have I experienced it before? And what if anything should I do? It also is the site for motor initiation. If you decided to make a little notation in your book just a moment ago, that decision came from this motor strip here. And so, the execution of voluntary motor activity is obviously initiated here in the cerebrum. It also is clearly where we store our memories, memories from early childhood, memories throughout our life. It's where we decide or make judgments as to what to do. Whether to come to class, whether to go to Costco or whatever, all of these are judgment calls. And then the ability to act appropriately, that is to exercise proper social behavior and to work out problems, that is to exercise critical thinking in the form of logic and so forth. You don't have this view but it's certainly one you've seen before. We're just cutting the brain, as you know, in a frontal way to recall this longitudinal fissure, maybe even the corpus callosum. And recall that the cerebrum is very convoluted. Is it not convoluted? You might recall this is your gyri and sulci. And the surface of the brain has an area that's not very deep but nevertheless dark and that's called the cerebral gray matter, also called the cerebral cortex. Everybody nods. OK, good. So this is all anatomical information that you've before and that we can probably skip over. But deep within the forebrain, here is seen in gold or yellow, is another component that is certainly subservient to the cerebrum but important as a relay center, it's called the thalamus. The thalamus is a bilateral structure of gray matter which incidentally is worth reviewing. In the cerebrum and throughout the central nervous system, there are two distinct colors, are there not? And those areas where you have myelin will be what color? Those areas that have a lot of myelin will be?

>> White.

>> White. And those that don't have myelin will be--

>> Gray.

>> --not white or gray. And so, that's something that you recall perhaps from anatomy. So the gray matter is gray because it represents congregations or aggregations of cell bodies. And the white matter is white because it represents tracts that is tracts of the--or myelinated axons. But back to thalamus, the thalamus is a relay center. That's what it's described as. And most sensory information passes through the thalamus eventually to reach select sites more often than not in the sensory part of the cortex. So the usual analogy that is used for the thalamus is that it's kind of a switchboard. What's a switchboard in a building, in a business is all of the phone lines coming there and then the calls are routed to certain offices or departments within that building. So, the thalamus determines crudely the nature of the sensory information then sends it on for a precise analysis by components of the cerebrum. The area below the thalamus is here in orange and has the obvious or useful name of hypothalamus. And despite its smaller size, the hypothalamus is loaded with important survival functions. Let's read it, food intake, water intake, body temperature, so what we call appetite and what we call thirst, all of these are made or controlled by the hypothalamus. It also is responsible for emotional expression. That is the way that you act out when you're emotional, whether you're kind of subdued or go hysterical, that's what we mean by emotional expression. And furthermore, it regulates much of the ANS. What's that? Autonomic nervous system. And as we learned, it controls this little tiny endocrine gland that sits below it in the sella turcica. That little spot there is the pituitary gland, also known as the hypophysis. So this area above the pituitary is the hypothalamus which has a great, many vegetative, that is life-support functions, so-called survival behaviors. And these can't be minimized because body temperature alone, is that something that can kill you? If body temperature goes awry then you've got serious problems in controlling that magic number, 98.6. Surrounding many of the ventricles, and you recall these ventricles that are filled with cerebral spinal fluid. The structure around the ventricles, here seen in red, form a complex system collectively called the limbic system. The word limbic means on the border. And so, these are here seen in blue for the most part. The limbic system, as you can read here, is concerned with being able to learn. And we learn through what? Why do we stop when the light is red? Because we learned that way long ago that that means stop or be killed. And so, learning is the function of recall, memory. What's interesting about the limbic system is that learning in memory has some apparent, shared functionality with emotion. That is the limbic system deals with emotional responses and learning in kind of a cooperative way and that might seem disconnected or unrelated. But what about this statement? This very familiar phrase, "math anxiety." Ever heard that? Math anxiety. What is that? Anxiety is a--an emotion, in math is learning, right? What's my point? Math anxiety is something that some people have because they're afraid of what? Math. And does that impede their ability to learn math? If you go into a math class and you say, "OMG, I hate math. I hate math. I'm not good at math. I failed math." Guess what? If you don't like something, if you basically have a very negative emotional sensitivity to it, is that going to affect your ability to learn it? Absolutely. And so if you

hate physiology, guess what? It's going to be hard. And so, I often think, you know, how do these people get through these courses about tax code? I couldn't be less interested in tax code. But there are people who spend their whole life as tax consultants and they love it, right? I couldn't care less. So what's my point? If you have an emotional attachment to something, does that enhance and improve your ability to succeed and to learn more and more about it? Obviously. So there's the connection between what we feel about something and our ability to master a particular topic. Moving on, that was a very quick review of the forebrain. And here's a very tight view of a sagittal brain. And OK, anatomy fans. This is--What's that gland again?

>> Pituitary.

>> Pituitary. So, here's the hypothalamus, thalamus is over here. You might recall the rest of this. Anyway, this area right here that I'm encircling which is obviously a connection between everything above and everything below, that is the midbrain. And it's more than just a bridge or a connecting body. But certainly, physically, it does connect what? The cerebrum with the pons and the cerebellum. So there's no denying it has a physical connectivity rule, that is information going north and south through the midbrain. If you really remember some anatomy, you might recall the term corpora quadrigemina. I know you probably blocked that out. But there's the corpora quadrigemina, the superior colliculus, the inferior colliculus. Anyway, these are centers that support hearing and visual reflexes. So, if you're just walking casually, minding your own business and somebody tiptoes up alongside, what happens? You turned to look. What is that? That's a visual reflex. On the other hand, if a horn goes off here in an automobile and you turned to look. That's not a visual reflex. That's an auditory or hearing reflex. So is the turning of the head in response to approaching sound or approaching movement? Is that important? Yeah, so that you can get out of the way if it's a bus or a thug or something like that. So, reflexes alert you to early threats that might be indeed life-threatening. There's more to say about the midbrain, but let's go now into this territory, all of these which lies below the midbrain is the hindbrain. And the biggest part of the hindbrain is the cerebellum which is a very pretty component, bilateral that is double-hemispheric structure that has this very interesting pattern of white matter and gray matter. Anyway, this is responsible for what? Subconscious muscle coordination and balance. None of us give this any thought at all but when you're walking, isn't it amazing that you can keep your balance even though the terrain might me irregular and that you can carry on a conversation and even juggle? I couldn't do that but I know people who could juggle three balls at a time and still walk across campus, six balls at a time, it's amazing. All of this is a function of what? Subconscious muscle coordination. The more common catch phrase here that you've heard is muscle memory. Muscle memory. If you talk to a gymnast or somebody who is an Olympic athlete whether it's the uneven parallel bars or the floor routine or whatever, and they come off that routine and they get their score and it's a 9.5, instead of a 10. Sometimes, the commentator shoves a mike in their face they'll say, "Well, you know, I just over thought that" or "I didn't let my muscle memory take over." And to me, that is fascinating because you see these routines where they're going from bar to bar and doing all these flips and they end up dismounting and just stick it every time. And you think, are they actually thinking about all those moves? No. What's doing it for them is their what? Their cerebellum. And how did they get programmed that way. Did they learn that routine yesterday? No. It's over and over and over and over again, practice, practice, practice to the point that it is just a system of moves that is more or less laid out automatically and they're certainly not involved, that is not they're not thinking about these moves because it's all processed, carried out by the hindbrain. And never mind muscle coordination, just balance. All of your sitting up fairly straight and you're not falling off your seat, you can thank the cerebellum. With that said and incidentally, this area is one of the first areas to be impaired by ethanol. Ethanol is what? So, what is one of the early, very diagnostic test that CHP people give to people who are suspected of perhaps being a little tipsy? Walk a straight line and that would naturally be impaired if the cerebellum is injured. Or even doing something like this, moving what? Moving your finger to your nose. Is that a cerebellar effect or process? Sure. So, anyway, the hindbrain important for these kinds of subconscious muscle movements. This area here is not the cerebellum. This area here which is right at the gateway to the spinal cord or foramen magnum is the medulla, also known as the medulla oblongata. Vital centers. What's the word vital mean? Necessary for life. And these vital centers control the action of your heart and blood vessels therefore blood pressure. Also control an initiation of respiration. So, if the medulla is destroyed, guess what? Game definitely over. In other words, you're dead. And so, this injury is something that cannot be survived. And with that said and quite amazingly, can you sustain considerable damage to the rest of your brain and still be alive? As long as your--what's intact? As long as your medulla is intact, is your heart still going to be beating? Is your blood pressure going to be OK? Are you still going to be breathing? Yes. And these people who have sustained massive injury--head injuries, may still be alive but they're in a permanent, vegetative state. That means they have no knowledge of anything and indeed for all practical purposes, their life is over. But in terms of their

warm body, is their warm body still going to be warm? And is this going to be still be moving blood and moving air and so forth? So these people are obviously beyond help, and at that point, if there is no brain activity, then we can perhaps ask the family to do what? People who are in a permanent vegetative state are candidates or at least their family would be asked whether they want to what, donate organs for those that are still alive. Traveling up through the medulla and extending actually into other parts of the hindbrain is the RAS which is an acronym for reticular activating system. And this is very diffuse. That is it's not a spot or structure that you can see with the naked eye. So I can't point to it and say, well, there's the RAS. It's really a network of fibers that runs from and through the medulla and the midbrain. But its function is important. It what? Filters, that means subdues or blocks repetitive stimuli and therefore essentially blocks overwhelming or superfluous information therefore allowing you to concentrate on things that are meaningful. And also this area--what does it say here, determines states of consciousness. That is whether you're alert like some of you are right now or not as some of you are right now. So, you can think or blame at the reticular activating system. And that's important also in a clinical sense because if this RAS is damaged, then you might have a condition which is very much like a permanent vegetative state which is called C-O-M-A. What's that? A coma from which you may or may not recover. And so, the ability to have no sensation and be in a unconscious state is due to at least temporary injury, perhaps to the RAS. The good news here is that this kind of trauma sometimes can be survived. That is the RAS may recover and are there instances then that people who have been in coma for a long time and then suddenly wake up. Is that possible, does it happen? Yes. So, unlike injury to the brain, traumatic injury to the brain which is often irreversible, damage to the RAS sometimes can be temporary. So, I know that that was very crude and inadequate coverage of the CNS. Let's finish off with just some connecting thought about the PNS which naturally is bringing signals to or signals away from the spinal cord and brain. And so, just to give organization and some terminology to these components, the sensory division, by definition, is made up of sensory nerves that are bringing signals in from the skin or joints and skeletal muscles, eventually to the spinal cord, eventually up to the brain. Remember these sensory nerves are traveling in these large bundles. What are these large bundles that you've dissected in anatomy already, the so-called nerve trunks or nerve bundles? So, sensory nerves are carrying their signals into the brain and ultimately for interpretation there. With that said, if the sensory nerve in the periphery is damaged or demyelinated or otherwise not functioning, what is going to be the clinical description of what happens? If this sensory nerve is damaged, demyelinated, or temporarily anesthetized, what is the patient going to complain about or otherwise report? Some degree of anesthesia. And many of you have experienced that if you've ever been in a dental chair and had your teeth worked on. Does the dentist find and anesthetized a particular peripheral nerve? And does that block temporarily these sensory fibers, and are you grateful for that? Well, I would be. I'd rather have nothing than, you know, jumping off the table. So, anesthesia, in this case, selective, selective damage or anesthesia to those nerves. Remember, in the saying "nerve trunk" though, there are fibers that are going the opposite way. That is these are those that are coming out this cord and traveling ultimately to muscles. So, these are called the motor fibers and many of these go to skeletal muscles. Those that do are called somatic motor nerves. There's three words. What? Somatic motor nerves. What's their destination? Skeletal muscles. With that said, what would be the expectation if we damage the somatic motor nerve? Well, you're going to have the P word, you're going to have some degree of paralysis. And by that, I mean you're going to have weakness of those muscles and that can be serious needless to say. Now remember, many peripheral nerves also contain autonomic nerves. And these are motor as well but their destination is very different. Where do these go? Smooth muscle in what? Cardiac muscle. These motor nerves do not instigate contraction but they control contraction. That is they accelerated or decelerated as the case may be. And so, we say these carry impulses, involuntary impulses, which adjust the activity of cardiac and smooth muscle. So as an example, is your heart rate fixed or is it subject to change? And can it go up and can it go down? Is that a function of somatic motor nerves? No. Because somatic motor nerves only supply or innervate skeletal muscles, so clearly as a function of autonomic motor nerves. And from anatomy you recall that the autonomic nervous system is subdivided into two antagonistic divisions, the sympathetic versus the parasympathetic. And it is a kind of versus, right, versus, meaning antagonistic. So in most settings, sympathetic have what effect? In most examples, sympathetic are excitatory and in many settings, parasympathetic are inhibitory, certainly in the example of the heart, that's true. So, using the heart as an example, if your increase sympathetic action, what will that do to the heart rate? On the other hand, if you increase parasympathetic action, that would slow it down. As a rule, and you recall this rule, most peripheral effectors like this receive not just sympathetic, not just parasympathetic, but both, and that relationship or anatomical fact is called dual what? Motor innervation. Very often compared to the control mechanisms in an automobile. I know I use this in anatomy, right? What are the two ways to control your vehicle, its speed anyway? Gas and brake, so that's dual motor innervation in a very real sense. So, with that said, what are two ways to speed up your car? Two ways, yes. You can speed up your car by what? Increasing the gas or taking your foot off the brake, all right. And what's the advantage? What's the physiological significance of dual motor innervation as it applies to your body?

Why not just have one? What's the advantage to having two means to control your car speed? Well, it gives you better control, more rapid, more rapid control over the action of that dual motor innervation, applies, not just the cardiac muscle but also the smooth muscle. Very interesting function of the autonomic nervous system. With all that said, what would be the clinical symptoms associated with injury to the autonomic motor division? Let's back up. Somatic motor nerves go where?

[Inaudible Remark]

And so if you damage those, you're going to have obvious paralysis. Now remember, autonomic nerves don't go to skeletal muscles. So would there be any paralysis expected with injury to any of the autonomic components? No, where do they go? They go to what? Smooth muscle and cardiac muscle. So you might think, oh, well, cardiac arrest. But wait a minute, the heart as you know is made of cardiac muscle. And that muscle is autorhythmic meaning it contracts all by itself. So, injury to the autonomic nervous system would not cause cardiac arrest, but remember, the key idea here is that these don't initiate, but they tend to control the activity or the speed of contraction of these muscles. So, without getting specific, that is without taking a particular example, what are some general things that might go awry if the autonomic nervous system would fail? Would there be irregularities of the heart? Would it be able to increase or decrease as it does when you are anxious or running or relaxed? So, there's that. And also smooth muscles. What are some of the organs that are regulated or at least made the move through smooth muscle action? The GI tract and blood vessels, the uterus, the bladder, so just all sorts of messy things can be imagined here and we can't summarize, but we will. What are some changes that would happen if the autonomic nervous system were impaired? There'll be GI what? What does that mean? GI, government issue? No, gastrointestinal. What does that mean? There's no point in writing it down. GI irregularities, or what's the opposite of irregular, that's regular. And so, when we think of our bowels, right? Don't we like to be regular? Anyway, so what am I alluding to? What are some two opposite GI irregularities, both of which are undesirable? Too much or too little and the too much is starting with the D word, diarrhea, and the too little is the C word, constipation. All right, so that's what we mean by GI irregularities. And what the heck do we mean by cardiovascular disturbances? Well, that means any upset in blood pressure, blood flow, heart rate, certainly arrhythmias. So, none of these would be instantly lethal necessarily, but certainly disruptive to these systems which carry out peristalsis and maintain blood pressure, and so on. So, I know that that's been quick and rather hasty you could say, but it's as far as we need to go tonight. So, let me just finish this off and we do have some time to review for tomorrow's exam, so I'm planning to do--