Key:

G = Dr. Gaede

G: Everything that you do, think and feel is controlled by your nervous system. From devising theorems to explain the mysteries of the universe and scaling Mount Everest, to simply just waking up, finding your way to the coffee maker in a zombie-like state, pouring your coffee and having that first sweet, sweet taste of caffeine -- these are all activities that we, as humans, are able to do, thanks to our nervous system.

In simple terms, how we experience the world can be reduced to three phases: sensory input, integration and motor output. For instance, say you're sitting at your desk working, and you hear your phone buzz. [BUZZ] This means that soundwaves have traveled through the air from your phone and into your ear, stimulating cells that allow you to process sound. Your nervous integrates this information and decides what to do. You move your head and eyeballs to look at your phone, which is a motor output driven by nervous system activation of certain muscles. Your visual system processes the lightwaves bouncing off your phone, and you see that it's your dentist calling -- again, the worst. Your nervous system processes the sensory input and decides how to respond. Do you simply hope that your teeth suddenly become self-cleaning, self-sustaining entities? Or do you answer the phone? Other information, like memories and emotions may influence your decision, and you do the cost benefit analysis of answering the phone.

Hello? Yeah, can I give you a call back? Thanks.

Ultimately you decide, perhaps against better judgment, to answer the call. But this motor output occurs only when your nervous system activates specific muscles.

Now let's talk about the nervous system itself. Of course, the nervous system is very complex and contains many layers. The brain and spinal cord form the Central Nervous System, or Mission Control. In humans, the brain is where complex ideas, predictions, plans and emotions are generated. The peripheral nervous system refers to the cranial and spinal nerves that allow communication between the Central Nervous System and the rest of your body.

As was illustrated in the phone call example, this communication must allow incoming and outgoing information. Therefore, the peripheral nervous system has both sensory, or incoming, and motor, or outgoing, divisions. Within the motor division, we have a sematic nervous system that is responsible for voluntary movement, and an autonomic nervous system that governs involuntary functions like heartrate and breathing. Within the autonomic system, there is another set of complementary systems; the sympathetic system which is responsible for the fight or flight response, and the parasympathetic system, which relaxes the body and lowers the heart rate.

So that is the broad organization of your nervous system, but no matter what part of the nervous system we're talking about, it is largely composed of two main classes of cells: neurons and glial cells. You are probably already familiar with neurons. These cells respond to stimuli and transmit signals and are generally thought of as the stars of the show. While there is no question that neurons are vital, glial cells are increasingly receiving more attention. Until recently, glial cells were described as the support network for neurons, which they are, but they are also more than that. There are several types of glial cells with a range of functions. They provide structural and nutritional support to neurons, assist signal transduction in the nervous system, protect against inflammation, perform housekeeping tasks, and likely much more. Nevertheless, when it comes to things like getting out of an escape room or writing a movie script, most of the work is being done by neurons. And thus, our discussion from here on out will focus on the structure and function of the esteemed, yet still humble, neuron, for which no amount awe is superfluous.

First, we will start out with three interesting pieces of neuron trivia. Neurons have incredible longevity, generally living as long as you do. Neurons do not divide like most cells, meaning that they cannot be replaced if destroyed. And finally, neurons have a very high metabolic rate. Your brain burns roughly 20 percent of the calories the average person needs a day.

Neurons come in a range of shapes and sizes, and have specialized functions, but they all have the same general structure. They have a central cell body from which a projection called an "axon" and a number of projections called "dendrites" extend. Axons send information, and dendrites receive information. Electrical impulses that drive communication between neurons travel down the axon, away from the cell body. Neurons send an impulse when they are activated by a sensory input or are triggered by a neighboring neuron.

There are three broad functional classes for neurons. Sensory receptors that carry information toward the Central Nervous System, also referred to as "afferent signals," motor neurons whose impulses move away from the Central Nervous System to muscles and the rest of the body, also called "efferent signals," and finally interneurons, which transmit impulses between neurons, including between sensory and motor neurons. An action potential is an electrical impulse, then initiates communication between neurons and from neurons to muscle cells. Action potentials are the only signal that neurons have, and they cannot alter the strength of the action potential or conduction speed down the axon. However, they can alter frequency. In other words, neurons can alter the number of impulses over time.

A weak stimulus will result in a low frequency of pulses, perhaps when you are using fine motor skills and want to delicately hold a paintbrush, whereas a strong stimulus result in a high frequency of pulses, like when you are doing some post-work power lifting. When an action potential travels down and hits the end of an axon, it has to cross a synapse, or a junction between two cells, to reach the next neuron. Each neuron has approximately 1,000 to 10,000 synapses. These structures are the centerpiece of the electrochemical signaling system in the human body. Synapses are involved in learning and memory, as well as many psychiatric disorders.

Components of the nervous system communicate using neurotransmitters. For example, you may have heard of the neurotransmitter "dopamine." This chemical messenger influences movement, learning, attention, and emotion, and can excite or inhibit neurons, depending on what receptors are present on the postsynaptic cell. Dopamine abnormalities have been linked to schizophrenia, as well as addictive and impulsive behaviors. Neurotransmitters are only briefly bound to receptors, after which they are reabsorbed by the pre-synaptic neuron or clear it away. Some pharmaceutical and illicit drugs act by mimicking neurotransmitters, or by altering the production, release, or reabsorption of neurotransmitters. Narcotics like heroin and other opioids trick the brain by altering its function at synapses. Over time, repeated use can cause the brain to change. It is important to understand that the chemistry of our brains influences how we think, sense, move and experience the world around us.

Neurotransmitters are not the only chemical messengers in the brain. The body's endocrine system is a slow-acting chemical communication system, and its messengers are hormones. Parts of the endocrine system communicate with each other, using hormones via the bloodstream. The nervous system and endocrine system work in concert with each other, and hormones can act on the brain. And some of them are chemically identical to neurotransmitters. Hormones affect attention, attraction, appetite, and aggression. While neurotransmitters are rapid and short-acting, hormones take time to be released from glands and distributed throughout the bloodstream. Hormones also hang around for a while, and in effect are longer-lasting than neurotransmitters, so while the nervous and endocrine systems are two messaging systems that use chemicals to target certain receptors, they operate at two very different speeds. Our bodies have a few important glands for producing hormones. The adrenal glands release adrenaline and are important for the fight or flight response. The pancreas releases hormones important for regulating how we absorb sugar. The thyroid and parathyroid glands excrete hormones that regulate metabolism and monitor calcium levels. Testes and ovaries secrete sex hormones. And the function of all of these glands is orchestrated by a teeny, tiny, pea-sized gland in the brain called the "pituitary gland." The pituitary releases hormones that control or stimulate other endocrine glands. It also releases human growth hormone, which is important for physical development, an oxytocin, the love hormone, which regulates social interaction and bonding.

Despite being the master gland, even the pituitary has a benevolent overlord, and that overlord is the hypothalamus, another brain structure that plays a key role in linking the nervous and endocrine systems, and among other things, controls aspects of homeostasis, hunger and circadian rhythms. So the general pathway that gets activated if you are startled, for instance, is that sensory information enters the brain, ultimately activating the hypothalamus, which sends signals down the pathway from the pituitary gland to the adrenals, which release adrenaline to the rest of your body. This, in turn, signals a cascade that returns information to the brain. This is called a feedback loop, and is a central mechanism used by the nervous system to regulate activity.

As I mentioned earlier, the role of the Central Nervous System, or CNS, is to integrate sensory information and coordinate both voluntary and involuntary responses, like, I am awake, therefore I must have coffee. That is a spider, so I should scream and run like a maniac. Or your back itches, so you scratch, or you're cold, so you shiver. The CNS consists of the brain and spinal cord. The adult brain is composed of four major components: the cerebrum, the diencephalon, or interbrain, the cerebellum and the brainstem. The brainstem has three major structures: the midbrain, the pons, and the medulla oblongata. Together, these parts regulate many basic, involuntary functions that are critical for life, like heartrate, breathing, digestion, pain sensitivity, and awareness.

The midbrain process is sensory information and sends out reflexive motor signals so that you can respond without thinking. So, if you saw a foul ball come flying in your direction, the midbrain would play a role in your reflexive response to duck. The midbrain also passes information to the cerebrum, which is involved in actually thinking about and developing a conscious response to a stimulus. The pons relays information between the cerebrum and the cerebellum, and the medulla oblongata controls involuntary functions critical for life, like blood pressure and breathing.

Cerebellum is Latin for "little brain." The cerebellum integrates many types of information and plays an important role in motor control and sensory motor signal processing. The cerebellum is essential for motor learning, particularly by learning to respond to changes in sensory motor relationships. The cerebellum may also be involved in cognitive functions like language, and attention orienting.

The diencephalon contains the thalamus and hypothalamus. These structures control things like homeostasis, alertness, and reproductive activity. Remember, the hypothalamus controls the pituitary gland, which regulates hormones to creation throughout the body. The diencephalon also contains part of the limbic system, which supports functions including emotion, motivation, long-term memory, and olfaction.

Finally, the cerebrum is made up of two cerebral hemispheres, and is the largest part of the brain and performs the highest functions. The thin, outer layer is called the cerebral cortex, and is made up of gray matter, and the interior is made of white matter. The cerebrum is responsible for our voluntary behaviors, and many of our interactions with the external environment. It also plays a key role in higher level functions, like memory, attention, perception, cognition, awareness, thought, language, and consciousness. Our cerebrum is important for thinking, learning, and regulating, and recognizing emotions.

It is important to think of the brain as a complex network, and to understand that at any given time, many different parts of your Central Nervous System are working together to filter and process abundant incoming information to develop appropriate responses. So let me leave you with a few final thoughts. The future of neuroscience research is grounded in understanding the circuits of the brain, the changing patterns of electrical and chemical activity, and how these functional connections create our unique and rich cognitive and behavioral repertoire. Researchers are working now to develop novel tools to explore these topics. Teasing apart the links between brain function and behavior will have widespread impact across society and be of particular interest to legal professionals. Furthermore, it is essential to consider the ethical questions related to new neuro-technologies and emerging areas of research so that one understands evolving regulations and the rationale behind these regulations.

Thank you.