NEUROLOGICAL DISORDERS
Welcome to the Neurological Disorders Module!

This module focuses on how our brains work, as well as how disorders and our choices change our brains. The Neurological Disorders (ND) Module has five units, each of which builds upon the others that came before it. The goal of each unit is to answer a new question about how our brains function.

- **Unit 1:** What do our brains need to do?
- **Unit 2:** What are the building blocks of our brains?
- **Unit 3:** How do our neurons communicate with each other?
- **Unit 4:** How do our neurons work together to control behaviors?
- **Unit 5:** How do our choices change our brains?

In Unit 1, we’ll begin our discussion by investigating what it is that our brains need to do. From there, in Unit 2, we’ll zoom in on the neuron, which is the basic building block of our brains. Then, in Unit 3, we’ll focus on the synapse, which is how neurons communicate with each other. Next, in Unit 4, we’ll take a larger approach and examine the circuit, which is how neurons work together to control behaviors. Finally, in Unit 5, using the example of drug addiction, we’ll look at how our choices change our brains.

To help orient you on how these topics relate to each other, we’ve put together the following graphic that you’ll see at the beginning of each unit. Notice how these topics relate to each other not only in content but also in size. Our brains are composed of circuits, which are composed of synapses, and synapses are the “junctiões” between two neurons.

Throughout this module, you’ll have not only class lessons, but also this workbook to guide you through your exploration of Neurological Disorders. This workbook is designed to provide you with readings to complement your class lessons. We have helped make your reading of this workbook interactive by encouraging you to take notes and answer questions throughout.
This unit introduces you to how we can study our brains - both how they are built, and how they function. In this lesson, we will begin our exploration by examining how scientists and doctors have historically tried to study the behaving brain.

How can we study our brains?

Your brain is the most important organ in your body. It controls your organs, your behavior and your memories and emotions. Without it, none of these would function – and you wouldn’t be aware of it, because the brain also controls the very basis for human consciousness. Perhaps the last frontier of biological science – its ultimate challenge – is to understand the exact mental processes within the brain that allow us to perceive and act, learn and remember – the biological basis of consciousness. Until recently, most of what we could glean about the behaving brain came from comparing the behavior of people with brains that had been damaged, with people apparently behaving normally. As we shall see, this approach has provided some interesting clues, but doesn’t give an insight into normal behavior.

Today, we are at the beginning of a technological revolution. Scientists and engineers have developed instruments that have opened unprecedented windows into the living brain. Techniques that can visualize living neurons behaving in real time have allowed us to view the normal brain as we are thinking, feeling and acting. Researchers can now see which parts of the brain are activated when we eat, sleep, listen to music, dance, meditate or do any number of other activities. On top of this, advances in computing power have allowed us to build machines that are increasingly able to function like actual brains. As young people at the beginning of the 21st century you will be participating in the final frontier - as we gather the tools to ask the question “What does it mean to be human?”
The first – and most famous – brain injury case that scientists used to investigate the relationship between the brain and behavior occurred in the mid-1800s. Phineas Gage was the foreman of a railway construction crew, and by all accounts was a model citizen, serious, industrious and energetic. One day, while using a steel rod to ram a charge of blasting powder into a hole, the charge suddenly exploded, sending the rod into Gage's cheek, through his brain, and out the top of his head! (Figure 1). Incredibly he survived, even walking away from the blast once he regained consciousness. But the Phineas that woke up after the accident was a very different man. He became childish and feckless, producing outbursts of temper that led some friends to remark that it looked as if Dr. Jekyll had become Mr. Hyde.

The very fact that Gage had survived such a terrible accident put him under intense medical scrutiny. Add to that the dramatic changes in personality that resulted from the accident, and you have one of the most famous case studies in neuroscience history. After years of observing his new reactions to situations, his doctors came to the conclusion that the front portions of his brain that had been damaged must be critical for controlling a rather subtle aspect of our personality that we now refer to as “executive function” – which is basically a filter that stops you saying the things you think, but know you shouldn’t say, or doing the things you’d like to, but know aren’t a good idea. Gage’s accident destroyed this filter so he just blurted out whatever came to mind, and got tangled up in all kinds of ill-advised schemes.

(You can see Phineas Gage’s skull and the iron bar at the Warren Anatomical Museum at Harvard Medical School, 10 Shattuck St., Boston, MA – it’s open Monday – Friday, 9-5.)
Another famous case of brain injury affecting totally different brain areas was that of Henry Gustav Molaison, known in the medical and scientific literature as ‘Patient H.M.:’ Born in 1926, Molaison suffered from severe epilepsy that left him almost totally unable to function. In 1953, surgeons attempted to treat it by removing areas in both the right and left side of his brain just above the ears (Figure 2). The surgery was successful and H.M.’s epilepsy disappeared. Unfortunately, the epilepsy was replaced by an equally debilitating memory impairment. H.M. woke up from the operation suffering from severe anterograde amnesia, meaning that although he could remember events from his past, he couldn’t make any new memories and therefore couldn't learn anything new. As a result he wasn’t able to remember people he met after the operation, and when his family moved to a new house, he was never able to learn how to get around in the new neighborhood.

The famous Canadian neurologist, Brenda Milner, made it her life’s work to study what exactly had happened when those parts of H.M.’s brain had been removed. By painstakingly giving him many different kinds of memory and recall tasks, Milner was not only able to determine the parts of the brain that are critical for the formation of new memories, she was also able to figure out that there are several different kinds of memory and our brains process each kind differently. We’ll talk more about this later.

You can hear a fascinating interview with Dr. Milner and H.M. online - see this unit on the student website or click below:

- **Audio:** H.M.’s Brain and the History of Memory

Although no other patient has had the same surgery as H.M., similar cases of brain damage can occur after illness. One of the most striking is Clive Wearing who was an eminent musician who contracted viral encephalitis (an infection that destroyed part of his brain). Clive Wearing suffers from both anterograde and retrograde amnesia so he retains memories for less than a minute, which means he is in a constant state of believing he has just woken up.

You can watch Clive Wearing and hear his wife and doctor describe what his life is like online - see this unit on the student website or click below:

- **Video:** Life Without Memory: The Case of Clive Wearing
Can we only study the brain using cases of injury or disease?

Much of what we know about the brain and how it functions has come from scientists and doctors who have studied cases of brain disease and injury, but we no longer have to rely on finding new cases in order to investigate how our brains work. Dramatic new advances in technology have given us a plethora of different tools that can be used to study the healthy, behaving brain. As we shall see, we are now able to literally eavesdrop on the brain while subjects are involved in any number of activities, from listening to music, reacting to a joke or watching a magic trick.

Can we use what we know to control someone else’s brain?

How likely is it that once we know exactly how the brain functions that we will be able to control another person’s brain? It sounds like science fiction, but we can actually do it right now, even with the limited knowledge we have. Transcranial magnetic stimulation (TMS) uses magnetic energy to send pulses of magnetic energy into the brain through the skull. In this way it can activate or disrupt the functioning of specific brain regions (Figure 3). TMS is noninvasive and extensive studies have shown it to be safe, so its been approved for use in humans by the Food and Drug Administration (FDA), which is the drug and medical appliance safety watchdog. TMS can be precisely aimed at specific brain regions and has been used to trigger ordinary people’s inner mathematical genius and to invoke religious experiences. There are hopes it could be used to help people with depression and other brain disorders such as schizophrenia and bipolar disorder, which have all been linked to specific areas.

While TMS has also been used to study the brain areas involved in moral decision making, it’s far from the “mind control” displayed in science fiction movies, but it’ll be an invaluable tool as we continue to study brain areas and their functions. In a later lesson, we’ll look at other techniques to visualize specific brain areas involved in normal behaviors.

Figure 3: Transcranial magnetic stimulation (TMS). TMS is a noninvasive procedure that uses magnetic pulses to stimulate different brain areas.
What do you see as some of the disadvantages in trying to determine how the brain functions from studying cases of injury or disease?

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What are some of the advantages of using modern day technologies to investigate how the brain functions?

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Do you think we’ll ever get to a stage where we will be able to completely control the brain? Why or why not?

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