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# Chapter 1 - History of Cognitive Psychology

## Definition of Cognitive Psychology

Imagine all of your thoughts as if they were physical entities, swirling rapidly inside your

mind. How is it possible that the brain is able to move from one thought to the next in an organized, orderly fashion? The brain is endlessly perceiving, processing, planning, organizing, and remembering—it is always active. Yet, you don't notice most of your brain's activity as you move throughout your daily routine. This is only one facet of the complex processes involved in cognition. Simply put, cognition is thinking, and it encompasses the processes associated with perception, knowledge, problem solving, judgment, language, and memory. Scientists who study cognition are searching for ways to understand how we integrate, organize, and utilize our conscious cognitive experiences without being aware of all of the unconscious work that our brains are doing (for example, Kahneman, 2011).

## **Cognition**

Upon waking each morning, you begin thinking—contemplating the tasks that you must complete that day. In what order should you run your errands? Should you go to the bank, the cleaners, or the grocery store first? Can you get these things done before you head to class or will they need to wait until school is done? These thoughts are one example of cognition at work. Exceptionally complex, cognition is an essential feature of human consciousness, yet not all aspects of cognition are consciously experienced.

Cognitive psychology is the field of psychology dedicated to examining how people think. It attempts to explain how and why we think the way we do by studying the interactions among human thinking, emotion, creativity, language, and problem solving, in addition to other cognitive processes. Cognitive psychologists strive to determine and measure different types of intelligence, why some people are better at problem solving than others, and how emotional intelligence affects success in the workplace, among countless other topics. They also sometimes focus on how we organize thoughts and information gathered from our environments into meaningful categories of thought, which will be discussed later.

## **Historical Roots: History of Cognition**

*“Cognition” is a term for a wide swath of mental functions that relate to knowledge and information processing.*

## **Cogito Ergo Sum**

Maybe you've heard the phrase *I think, therefore I am*, or perhaps even the Latin version: *Cogito ergo sum*. This simple expression is one of enormous philosophical importance, because it is about the act of thinking. Thought has been of fascination to humans for many centuries, with questions like *What is thinking?* and *How do people think?* and *Why do people think?* troubling and intriguing many philosophers, psychologists, scientists, and others. The word "cognition" is the closest scientific synonym for thinking. It comes from the same root as the Latin word *cogito*, which is one of the forms of the verb "to know." Cognition is the set of all mental abilities and processes related to knowledge, including attention, memory, judgment, reasoning, problem solving, decision making, and a host of other vital processes. Human cognition takes place at both conscious and unconscious levels. It can be concrete or abstract. It is intuitive, meaning that nobody has to learn or be taught how to think. It just happens as part of being human. Cognitive processes use existing knowledge but are capable of generating new knowledge through logic and inference.

## **History of Cognition**

People have been studying knowledge in various ways for centuries. Some of the most important figures in the study of cognition are:

### ***Aristotle (384–322 BCE)***

The study of human cognition began over two thousand years ago. The Greek philosopher Aristotle was interested in many fields, including the inner workings of the mind and how they affect the human experience. He also placed great importance on ensuring that his studies and ideas were based on empirical evidence (scientific information that is gathered through observation and careful experimentation).

### ***Descartes (1596–1650)***

René Descartes was a seventeenth-century philosopher who coined the famous phrase *I think, therefore I am* (albeit in French). The simple meaning of this phrase is that the act of thinking proves that a thinker exists. Descartes came up with this idea when trying to prove whether anyone could truly know anything despite the fact that our senses sometimes deceive us. As he explains, "We cannot doubt of our existence while we doubt."

### ***Wilhelm Wundt (1832–1920)***

Wilhelm Wundt is considered one of the founding figures of modern psychology; in fact, he was the first person to call himself a psychologist. Wundt believed that scientific psychology should focus on introspection, or analysis of the contents of one's own mind and experience. Though today Wundt's methods are recognized as being subjective and unreliable, he is one of the important figures in the study of cognition because of his examination of human thought processes.

## **Cognition, Psychology, and Cognitive Science**

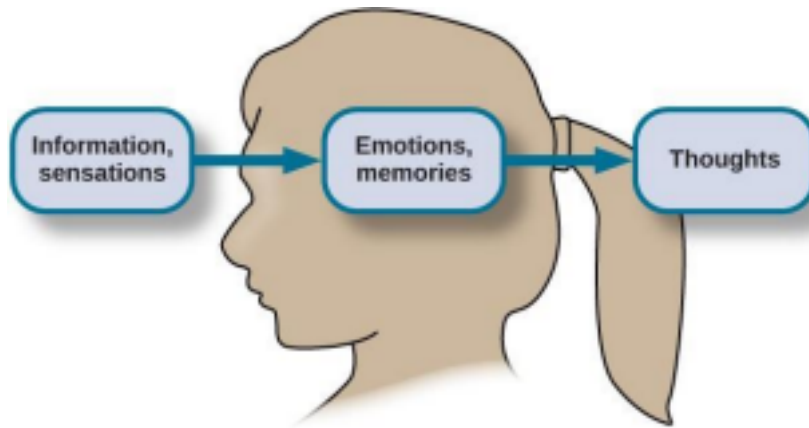
The term "cognition" covers a wide swath of processes, everything from memory to attention. These processes can be analyzed through the lenses of many different fields: linguistics, anesthesia, neuroscience, education, philosophy, biology, computer science, and of course, psychology, to name a few. Because of the number of disciplines that study cognition to some degree, the term can have different meanings in different contexts. For example, in psychology, "cognition" usually refers to processing of neural information; in social psychology the term "social cognition" refers to attitudes and group attributes. These numerous approaches to the analysis of cognition are synthesized in the relatively new field of cognitive science, the interdisciplinary study of mental processes and functions.

## **Mnemonic Devices**

### **What is the nature of thought/how is it organized?**

#### ***Concepts and Prototypes***

The human nervous system is capable of handling endless streams of information. The senses serve as the interface between the mind and the external environment, receiving stimuli and translating it into nervous impulses that are transmitted to the brain. The brain then processes this information and uses the relevant pieces to create thoughts, which can then be expressed through language or stored in memory for future use. To make this process more complex, the brain does not gather information from external environments only. When thoughts are formed, the brain also pulls information from emotions and memories. Emotion and memory are powerful influences on both our thoughts and behaviors.



*Figure 1. Sensations and information are received by our brains, filtered through emotions and memories, and processed to become thoughts.*

In order to organize this staggering amount of information, the brain has developed a file cabinet of sorts in the mind. The different files stored in the file cabinet are called concepts. Concepts are categories or groupings of linguistic information, images, ideas, or memories, such as life experiences. Concepts are, in many ways, big ideas that are generated by observing details, and categorizing and combining these details into cognitive structures. You use concepts to see the relationships among the different elements of your experiences and to keep the information in your mind organized and accessible.

Concepts are informed by our semantic memory (you learned about this concept when you studied memory) and are present in every aspect of our lives; however, one of the easiest places to notice concepts is inside a classroom, where they are discussed explicitly. When you study United States history, for example, you learn about more than just individual events that have happened in America's past. You absorb a large quantity of information by listening to and participating in discussions, examining maps, and reading first-hand accounts of people's lives. Your brain analyzes these details and develops an overall understanding of American history. In the process, your brain gathers details that inform and refine your understanding of related concepts like democracy, power, and freedom.

Concepts can be complex and abstract, like justice, or more concrete, like types of birds. In psychology, for example, Piaget's stages of development are abstract concepts. Some concepts, like tolerance, are agreed upon by many people, because they have been used in various ways over many years. Other concepts, like the characteristics of your ideal friend or your family's birthday traditions, are personal and individualized. In this way, concepts touch every aspect of our lives, from our many daily routines to the guiding principles behind the way governments function.

Another technique used by your brain to organize information is the identification of prototypes for the concepts you have developed. A prototype is the best example or representation of a concept. For example, for the category of civil disobedience, your

prototype

could be Rosa Parks. Her peaceful resistance to segregation on a city bus in Montgomery, Alabama, is a recognizable example of civil disobedience. Or your prototype could be Mohandas Gandhi, sometimes called Mahatma Gandhi (“Mahatma” is an honorific title).



*Figure 2. In 1930, Mohandas Gandhi led a group in peaceful protest against a British tax on salt in India.*

Mohandas Gandhi served as a nonviolent force for independence for India while simultaneously demanding that Buddhist, Hindu, Muslim, and Christian leaders—both Indian and British— collaborate peacefully. Although he was not always successful in preventing violence around him, his life provides a steadfast example of the civil disobedience prototype (Constitutional Rights Foundation, 2013). Just as concepts can be abstract or concrete, we can make a distinction between concepts that are functions of our direct experience with the world and those that are more artificial in nature.

### ***Natural and Artificial Concepts***

In psychology, concepts can be divided into two categories, natural and artificial. Natural concepts are created “naturally” through your experiences and can be developed from either direct or indirect experiences. For example, if you live in Essex Junction, Vermont, you have probably had a lot of direct experience with snow. You’ve watched it fall from the sky, you’ve seen lightly falling snow that barely covers the windshield of your car, and you’ve shoveled out 18 inches of fluffy white snow as you’ve thought, “This is perfect for skiing.” You’ve thrown snowballs at your best friend and gone sledding down the steepest hill in town. In short, you know snow. You know what it looks like, smells like, tastes like, and feels like. If, however, you’ve lived your whole life on the island of Saint Vincent in the Caribbean, you may never have actually seen snow, much less tasted, smelled, or touched it. You know snow from the indirect

experience of seeing pictures of falling snow—or from watching films that feature snow as part of the setting. Either way, snow is a natural concept because you can construct an understanding of it through direct observations or experiences of snow.

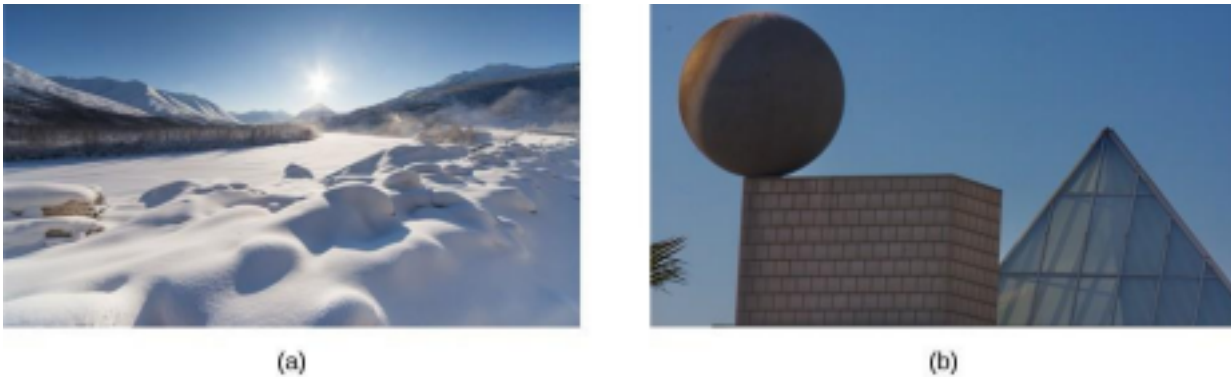


Figure 3. (a) Our concept of snow is an example of a natural concept—one that we understand through direct observation and experience. (b) In contrast, artificial concepts are ones that we know by a specific set of characteristics that they always exhibit, such as what defines different basic shapes. (credit a: modification of work by Maarten Takens; credit b: modification of work by “Shayan (USA)”/Flickr)

An artificial concept, on the other hand, is a concept that is defined by a specific set of characteristics. Various properties of geometric shapes, like squares and triangles, serve as useful examples of artificial concepts. A triangle always has three angles and three sides. A square always has four equal sides and four right angles. Mathematical formulas, like the equation for area ( $\text{length} \times \text{width}$ ) are artificial concepts defined by specific sets of characteristics that are always the same. Artificial concepts can enhance the understanding of a topic by building on one another. For example, before learning the concept of “area of a square” (and the formula to find it), you must understand what a square is. Once the concept of “area of a square” is understood, an understanding of area for other geometric shapes can be built upon the original understanding of area. The use of artificial concepts to define an idea is crucial to communicating with others and engaging in complex thought. According to Goldstone and Kersten (2003), concepts act as building blocks and can be connected in countless combinations to create complex thoughts.

### **Schemata**

A schema is a mental construct consisting of a cluster or collection of related concepts (Bartlett, 1932). There are many different types of schemata, and they all have one thing in common: schemata are a method of organizing information that allows the brain to work more efficiently. When a schema is activated, the brain makes immediate assumptions about the person or object being observed.

There are several types of schemata. A role schema makes assumptions about how individuals in certain roles will behave (Callero, 1994). For example, imagine you meet someone who introduces himself as a firefighter. When this happens, your brain automatically activates the “firefighter schema” and begins making assumptions that

this person is brave, selfless, and community-oriented. Despite not knowing this person, already you have unknowingly made judgments about him. Schemata also help you fill in gaps in the information you receive from the world around you. While schemata allow for more efficient information processing, there can be problems with schemata, regardless of whether they are accurate: Perhaps this particular firefighter is not brave, he just works as a firefighter to pay the bills while studying to become a children's librarian.

An event schema, also known as a cognitive script, is a set of behaviors that can feel like a routine. Think about what you do when you walk into an elevator. First, the doors open and you wait to let exiting passengers leave the elevator car. Then, you step into the elevator and turn around to face the doors, looking for the correct button to push. You never face the back of the elevator, do you? And when you're riding in a crowded elevator and you can't face the front, it feels uncomfortable, doesn't it? Interestingly, event schemata can vary widely among different cultures and countries. For example, while it is quite common for people to greet one another with a handshake in the United States, in Tibet, you greet someone by sticking your tongue out at them, and in Belize, you bump fists (Cairns Regional Council, n.d.)



Figure 4. What event schema do you perform when riding in an elevator? (credit: "Gideon"/Flickr)

Because event schemata are automatic, they can be difficult to change. Imagine that you are driving home from work or school. This event schema involves getting in the car, shutting the door, and buckling your seatbelt before putting the key in the ignition. You might perform this script two or three times each day. As you drive home, you hear your phone's ring tone. Typically, the event schema that occurs when you hear your phone ringing involves locating the phone and answering it or responding to your latest text message. So without thinking, you reach for your phone, which could be in your pocket, in your bag, or on the passenger seat of the car. This powerful event schema is informed by your pattern of behavior and the pleasurable stimulation that a phone call

or text message gives your brain. Because it is a schema, it is extremely challenging for us to stop reaching for the phone, even though we know that we endanger our own lives and the lives of others while we do it (Neyfakh, 2013).



Figure 5. Texting while driving is dangerous, but it is a difficult event schema for some people to resist.

Remember the elevator? It feels almost impossible to walk in and *not* face the door. Our powerful event schema dictates our behavior in the elevator, and it is no different with our phones. Current research suggests that it is the habit, or event schema, of checking our phones in many different situations that makes refraining from checking them while driving especially difficult (Bayer & Campbell, 2012). Because texting and driving has become a dangerous epidemic in recent years, psychologists are looking at ways to help people interrupt the “phone schema” while driving. Event schemata like these are the reason why many habits are difficult to break once they have been acquired. As we continue to examine thinking, keep in mind how powerful the forces of concepts and schemata are to our understanding of the world.

## **Summary**

In this section, you were introduced to cognitive psychology, which is the study of cognition, or the brain’s ability to think, perceive, plan, analyze, and remember. Concepts and their corresponding prototypes help us quickly organize our thinking by creating categories into which we can sort new information. We also develop schemata, which are clusters of related concepts. Some schemata involve routines of thought and behavior, and these help us function properly in various situations without having to “think twice” about them. Schemata show up in social situations and routines of daily behavior.

## **Self Check Questions**

### **Critical Thinking Questions**

1. Describe a social schema that you would notice at a sporting event.
2. Explain why event schemata have so much power over human behavior.

### **Personal Application Question**

3. Describe a natural concept that you know fully but that would be difficult for

someone else to understand and explain why it would be difficult.

## Answers

1. Answers will vary. When attending a basketball game, it is typical to support your team by wearing the team colors and sitting behind their bench.
2. Event schemata are rooted in the social fabric of our communities. We expect people to behave in certain ways in certain types of situations, and we hold ourselves to the same social standards. It is uncomfortable to go against an event schema—it feels almost like we are breaking the rules.

## Glossary

- **Artificial Concept:** concept that is defined by a very specific set of characteristics
- **Cognition:** thinking, including perception, learning, problem solving, judgment, and memory
- **Cognitive Psychology:** field of psychology dedicated to studying every aspect of how people think
- **Concept:** category or grouping of linguistic information, objects, ideas, or life experiences
- **Cognitive Script:** set of behaviors that are performed the same way each time; also referred to as an event schema
- **Event Schema:** set of behaviors that are performed the same way each time; also referred to as a cognitive script
- **Natural Concept:** mental groupings that are created “naturally” through your experiences
- **Prototype:** best representation of a concept
- **Role Schema:** set of expectations that define the behaviors of a person occupying a particular role
- **Schema:** (plural = schemata) mental construct consisting of a cluster or collection of related concepts

## Early Psychology—Structuralism and Functionalism

Psychology is a relatively young science with its experimental roots in the 19th century, compared, for example, to human physiology, which dates much earlier. As mentioned, anyone interested in exploring issues related to the mind generally did so in a philosophical context prior to the 19th century. Two men, working in the 19th century, are generally credited as being the founders of psychology as a science and academic discipline that was distinct from philosophy. Their names were Wilhelm Wundt and William James.

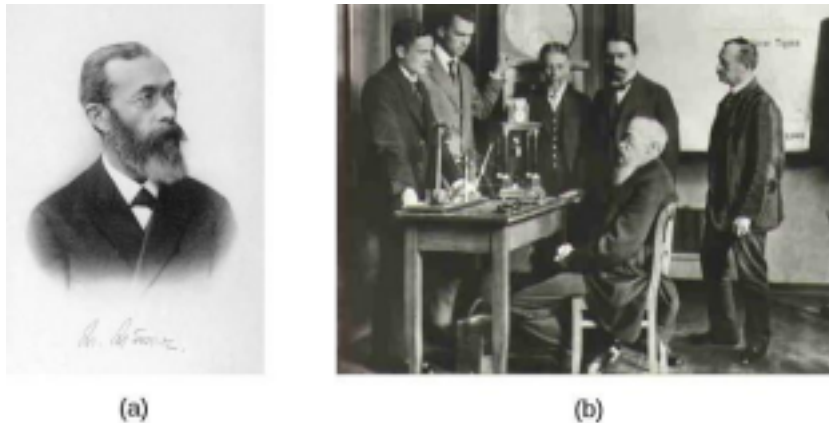
School of psychology	Description	Important contributors
Structuralism	Uses the method of introspection to identify the basic elements or “structures” of psychological experience	Wilhelm Wundt, Edward B. Titchener
Functionalism	Attempts to understand why animals and humans have developed the particular psychological aspects that they currently possess	William James
Psychodynamic	Focuses on the role of our unconscious thoughts, feelings, and memories and our early childhood experiences in determining behavior	Sigmund Freud, Carl Jung, Alfred Adler, Erik Erickson
Behaviorism	Based on the premise that it is not possible to objectively study the mind, and therefore that psychologists should limit their attention to the study of behavior itself	John B. Watson, B. F. Skinner
Cognitive	The study of mental processes, including perception, thinking, memory, and judgments	Hermann Ebbinghaus, Sir Frederic Bartlett, Jean Piaget
Social-cultural	The study of how the social situations and the cultures in which people find themselves influence thinking and behavior	Fritz Heider, Leon Festinger, Stanley Schachter

Table 1. The Most Important Approaches (Schools) of Psychology

## Wundt and Structuralism

Wilhelm Wundt (1832–1920) was a German scientist who was the first person to be referred to as a psychologist. His famous book entitled *Principles of Physiological Psychology* was published in 1873. Wundt viewed psychology as a scientific study of conscious experience, and he believed that the goal of psychology was to identify components of consciousness and how those components combined to result in our conscious experience. Wundt used introspection (he called it “internal perception”), a process by which someone examines their own conscious experience as objectively as possible, making the human mind like any other aspect of nature that a scientist observed. Wundt’s version of introspection used only very specific experimental conditions in which an external stimulus was designed to produce a scientifically

observable (repeatable) experience of the mind (Danziger, 1980). The first stringent requirement was the use of “trained” or practiced observers, who could immediately observe and report a reaction. The second requirement was the use of repeatable stimuli that always produced the same experience in the subject and allowed the subject to expect and thus be fully attentive to the inner reaction. These experimental requirements were put in place to eliminate “interpretation” in the reporting of internal experiences and to counter the argument that there is no way to know that an individual is observing their mind or consciousness accurately, since it cannot be seen by any other person. This attempt to understand the structure or characteristics of the mind was known as **structuralism**. Wundt established his psychology laboratory at the University at Leipzig in 1879. In this laboratory, Wundt and his students conducted experiments on, for example, reaction times. A subject, sometimes in a room isolated from the scientist, would receive a stimulus such as a light, image, or sound. The subject’s reaction to the stimulus would be to push a button, and an apparatus would record the time to reaction. Wundt could measure reaction time to one-thousandth of a second (Nicolas & Ferrand, 1999).



*Figure 6. (a) Wilhelm Wundt is credited as one of the founders of psychology. He created the first laboratory for psychological research. (b) This photo shows him seated and surrounded by fellow researchers and equipment in his laboratory in Germany. However, despite his efforts to train individuals in the process of introspection, this process remained highly subjective, and there was very little agreement between individuals. As a result, structuralism fell out of favor with the passing of Wundt’s student, Edward Titchener, in 1927 (Gordon, 1995).*

[Follow the link for a deeper look at Structuralism & Functionalism](#)

## Structuralism & Functionalism James and

### Functionalism

William James (1842–1910) was the first American psychologist who espoused a different perspective on how psychology should operate. James was introduced to Darwin's theory of evolution by natural selection and accepted it as an explanation of an organism's characteristics. Key to that theory is the idea that natural selection leads to organisms that are adapted to their environment, including their behavior. Adaptation means that a trait of an organism has a function for the survival and reproduction of the individual, because it has been naturally selected. As James saw it, psychology's purpose was to study the function of behavior in the world, and as such, his perspective was known as **functionalism**. Functionalism focused on how mental activities helped an organism fit into its environment. Functionalism has a second, more subtle meaning in that functionalists were more interested in the operation of the whole mind rather than of its individual parts, which were the focus of structuralism. Like Wundt, James believed that introspection could serve as one means by which someone might study mental activities, but James also relied on more objective measures, including the use of various recording devices, and examinations of concrete products of mental activities and of anatomy and physiology (Gordon, 1995).



Figure 7. William James, shown here in a self-portrait, was the first American psychologist.

### **GLOSSARY**

- **Functionalism:** focused on how mental activities helped an organism adapt to its environment
- **Structuralism:** understanding the conscious experience through introspection

## Ecological Validity

One important challenge researchers face when designing a study is to find the right balance between ensuring [internal validity](#), or the degree to which a study allows unambiguous causal inferences, and [external validity](#), or the degree to which a study ensures that potential findings apply to settings and samples other than the ones being studied ([Brewer, 2000](#)). Unfortunately, these two kinds of validity tend to be difficult to achieve at the same time, in one study. This is because creating a controlled setting, in which all potentially influential factors (other than the experimentally-manipulated variable) are controlled, is bound to create an environment that is quite different from what people naturally encounter (e.g., using a happy movie clip to promote helpful behavior). However, it is the degree to which an experimental situation is comparable to the corresponding real-world situation of interest that determines how generalizable potential findings will be. In other words, if an experiment is very far-off from what a person might normally experience in everyday life, you might reasonably question just how useful its findings are.

Because of the incompatibility of the two types of validity, one is often—by design—prioritized over the other. Due to the importance of identifying true causal relationships, psychology has traditionally emphasized internal over external validity. However, in order to make claims about human behavior that apply across populations and environments, researchers complement traditional laboratory research, where participants are brought into the lab, with field research where, in essence, the psychological laboratory is brought to participants. Field studies allow for the important test of how psychological variables and processes of interest “behave” under real-world circumstances (i.e., what *actually does happen* rather than what *can happen*). They can also facilitate “downstream” operationalizations of constructs that measure life outcomes of interest *directly* rather than indirectly.

Take, for example, the fascinating field of psychoneuroimmunology, where the goal is to understand the interplay of psychological factors - such as personality traits or one's stress level - and the immune system. Highly sophisticated and carefully controlled experiments offer ways to isolate the variety of neural, hormonal, and cellular mechanisms that link psychological variables such as chronic stress to biological outcomes such as immunosuppression (a state of impaired immune functioning; [Sapolsky, 2004](#)). Although these studies demonstrate impressively how psychological factors can affect health-relevant biological processes, they—because of their research design—remain mute about the degree to which these factors actually do undermine people's everyday health in real life. It is certainly important to show that laboratory stress can alter the number of natural killer cells in the blood. But it is equally important to test to what extent the levels of stress that people experience on a day-to-day basis result in them catching a cold more often or taking longer to recover from one. The goal for researchers, therefore, must be to complement traditional laboratory experiments with less controlled studies under real-world circumstances. The term [ecological](#)

**validity** is used to refer the degree to which an effect has been obtained under conditions that are typical for what happens in everyday life (Brewer, 2000). In this example, then, people might keep a careful daily log of how much stress they are under as well as noting physical symptoms such as headaches or nausea. Although many factors beyond stress level may be responsible for these symptoms, this more correlational approach can shed light on how the relationship between stress and health plays out outside of the laboratory.

## **Behaviorism**

### ***How do we act?***

Learning theories focus on how we respond to events or stimuli rather than emphasizing what motivates our actions. These theories provide an explanation of how experience can change what we are capable of doing or feeling.

### ***Classical Conditioning and Emotional Responses***

Classical Conditioning theory helps us to understand how our responses to one situation become attached to new situations. For example, a smell might remind us of a time when we

were a kid (elementary school cafeterias smell like milk and mildew!). If you went to a new cafeteria with the same smell, it might evoke feelings you had when you were in school. Or a song on the radio might remind you of a memorable evening you spent with your first true love. Or, if you hear your entire name (John Wilmington Brewer, for instance) called as you walk across the stage to get your diploma and it makes you tense because it reminds you of how your father used to use your full name when he was mad at you, you've been classically conditioned!

Classical conditioning explains how we develop many of our emotional responses to people or events or our "gut level" reactions to situations. New situations may bring about an old response because the two have become connected. Attachments form in this way. Addictions are affected by classical conditioning, as anyone who's tried to quit smoking can tell you. When you try to quit, everything that was associated with smoking makes you crave a cigarette.

### ***Pavlov***



Figure 8. Ivan Pavlov

Ivan Pavlov (1880-1937) was a Russian physiologist interested in studying digestion. As he recorded the amount of salivation his laboratory dogs produced as they ate, he noticed that they actually began to salivate before the food arrived as the researcher walked down the hall and toward the cage. "This," he thought, "is not natural!" One would expect a dog to automatically salivate when food hit their palate, but BEFORE the food comes? Of course, what had happened was . . . you tell me. That's right! The dogs knew that the food was coming because they had learned to associate the footsteps with the food. The key word here is "learned". A learned response is called a "conditioned" response. Pavlov began to experiment with this "psychic" reflex. He began to ring a bell, for instance, prior to introducing the food. Sure enough, after making this connection several times, the dogs could be made to salivate to the sound of a bell. Once the bell had become an event to which the dogs had learned to salivate, it was called a conditioned stimulus. The act of salivating to a bell was a response that had also been learned, now termed in Pavlov's jargon, a conditioned response. Notice that the response, salivation, is the same whether it is conditioned or unconditioned (unlearned or natural). What changed is the stimulus to which the dog salivates. One is natural (unconditioned) and one is learned (conditioned). Well, enough of Pavlov's dogs. Who cares?

Let's think about how classical conditioning is used on us. One of the most widespread applications of classical conditioning principles was brought to us by the psychologist, John B. Watson.

### ***Watson and Behaviorism***

Watson believed that most of our fears and other emotional responses are classically conditioned. He had gained a good deal of popularity in the 1920s with his expert advice on parenting offered to the public. He believed that parents could be taught to help shape their children's behavior and tried to demonstrate the power of classical conditioning with his famous experiment with an 18 month old boy named "Little Albert". Watson sat Albert down and introduced a variety of seemingly scary objects to him: a burning piece of newspaper, a white rat, etc. But Albert remained curious and reached for all of these things. Watson knew that one of our only inborn fears is the fear of loud noises so he proceeded to make a loud noise each time he introduced one of Albert's favorites, a white rat. After hearing the loud noise several times paired with the rat, Albert soon came to fear the rat and began to cry when it was introduced. Watson

filmed this experiment for posterity and used it to demonstrate that he could help parents achieve any outcomes they desired, if they would only follow his advice. Watson wrote columns in newspapers and in magazines and gained a lot of popularity among parents eager to apply science to household order. Parenting advice was not the legacy Watson left us, however. Where he really made his impact was in advertising. After Watson left academia, he went into the world of business and showed companies how to tie something that brings about a natural positive feeling to their products to enhance sales. Thus the union of sex and advertising! So, let's use a much more interesting example than Pavlov's dogs to check and see if you understand the difference between conditioned and unconditioned stimuli and responses. In the experiment with Little Albert, identify the unconditioned stimulus, the unconditioned response, and, after conditioning, the conditioned stimulus and the conditioned response.

### ***Operant Conditioning and Repeating Actions***

Operant Conditioning is another learning theory that emphasizes a more conscious type of learning than that of classical conditioning. A person (or animal) does something (operates something) to see what effect it might bring. Simply said, operant conditioning describes how we repeat behaviors because they pay off for us. It is based on a principle authored by a psychologist named Thorndike (1874-1949) called the law of effect. The law of effect suggest that we will repeat an action if it is followed by a good effect.

### ***Skinner and Reinforcement***

Watch a pigeon learn through the concept reinforcement.



#### **Watch**

B.F. Skinner (1904-199) expanded on Thorndike's principle and outlined the principles of operant conditioning. Skinner believed that we learn best when our actions are reinforced. For example, a child who cleans his room and is reinforced (rewarded) with a big hug and words of praise is more likely to clean it again than a child whose deed

goes unnoticed. Skinner believed that almost anything could be reinforcing. A reinforcer is anything following a behavior that makes it more likely to occur again. It can be something intrinsically rewarding (called intrinsic or primary reinforcers), such as food or praise, or it can be rewarding because it can be exchanged for what one really wants (such as using money to buy a cookie). Such reinforcers are referred to as secondary reinforcers or extrinsic reinforcers.

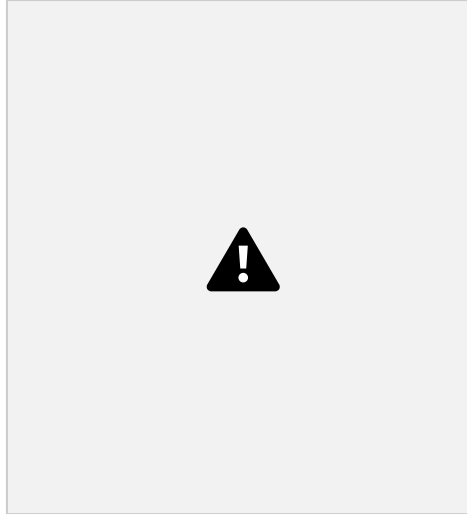


Figure 9. B. F. Skinner (1950)

### **Positive and negative reinforcement**

Sometimes, adding something to the situation is reinforcing as in the cases we described above with cookies, praise and money. Positive reinforcement involves adding something to the situation to encourage a behavior. Other times, taking something away from a situation can be reinforcing. For example, the loud, annoying buzzer on your alarm clock encourages you to get up so that you can turn it off and get rid of the noise. Children whine in order to get their parents to do something and often, parents give in just to stop the whining. In these instances, negative reinforcement has been used.

Operant conditioning tends to work best if you focus on trying to encourage a behavior or move a person into the direction you want them to go rather than telling them what not to do. Reinforcers are used to encourage a behavior; punishers are used to stop behavior. A punisher is anything that follows an act and decreases the chance it will reoccur. But often a punished behavior doesn't really go away. It is just suppressed and may reoccur whenever the threat of punishment is removed. For example, a child may not cuss around you because you've washed his mouth out with soap, but he may cuss around his friends. Or a motorist may only slow down when the trooper is on the side of the freeway. Another problem with punishment is that when a person focuses on punishment, they may find it hard to see what the other does right or well. And punishment is stigmatizing; when punished, some start to see themselves as bad and give up trying to change.

Reinforcement can occur in a predictable way, such as after every desired action is performed, or intermittently, after the behavior is performed a number of times or the first time it is performed after a certain amount of time. The schedule of reinforcement has an impact on how long a behavior continues after reinforcement is discontinued. So a parent who has rewarded a child's actions each time may find that the child gives up very quickly if a reward is not immediately forthcoming. A lover who is warmly regarded now and then may continue to seek out his or her partner's attention long after the partner has tried to break up. Think about the kinds of behaviors you may have learned through classical and operant conditioning. You may have learned many things in this way. But sometimes we learn very complex behaviors quickly and without direct reinforcement. Bandura explains how.

## **Gestalt Psychology**

In the early part of the 20th century, Max Wertheimer published a paper demonstrating that individuals perceived motion in rapidly flickering static images—an insight that came to him as he used a child's toy tachistoscope. Wertheimer, and his assistants Wolfgang Köhler and Kurt Koffka, who later became his partners, believed that perception involved more than simply combining sensory stimuli. This belief led to a new movement within the field of psychology known as Gestalt psychology. The word *gestalt* literally means form or pattern, but its use reflects the idea that the whole is different from the sum of its parts. In other words, the brain creates a perception that is more than simply the sum of available sensory inputs, and it does so in predictable ways. Gestalt psychologists translated these predictable ways into principles by which we organize sensory information. As a result, Gestalt psychology has been extremely influential in the area of sensation and perception (Rock & Palmer, 1990).

One Gestalt principle is the figure-ground relationship. According to this principle, we tend to segment our visual world into figure and ground. Figure is the object or person that is the focus of the visual field, while the ground is the background. As [\[link\]](#) shows, our perception can vary tremendously, depending on what is perceived as figure and what is perceived as ground. Presumably, our ability to interpret sensory information depends on what we label as figure and what we label as ground in any particular case, although this assumption has been called into question (Peterson & Gibson, 1994; Vecera & O'Reilly, 1998).

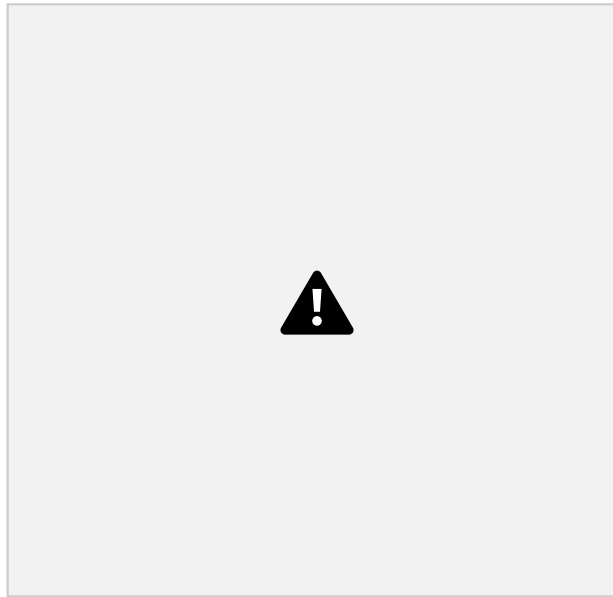


Figure 10. The concept of figure-ground relationship explains why this image can be perceived either as a vase or as a pair of faces.

Another Gestalt principle for organizing sensory stimuli into meaningful perception is proximity. This principle asserts that things that are close to one another tend to be grouped together, as is illustrated in the image below.

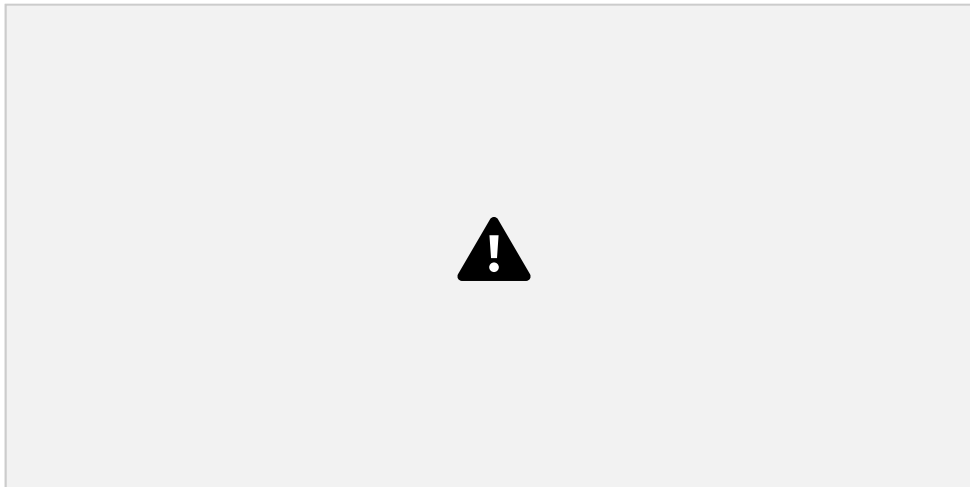


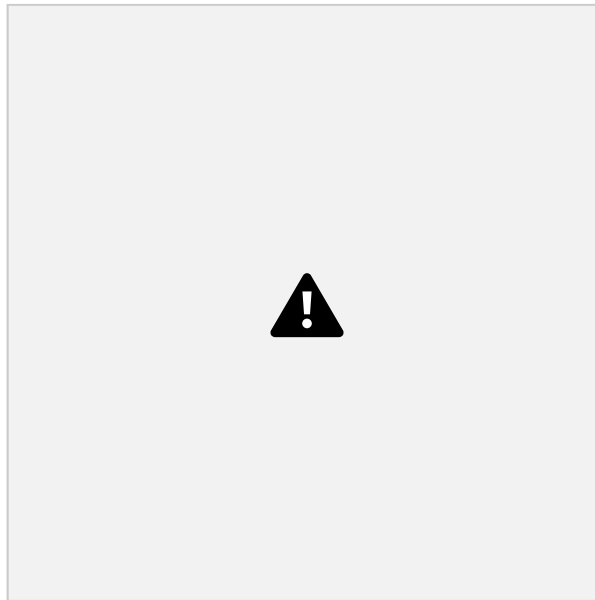
Figure 11.

The Gestalt principle of proximity suggests that you see (a) one block of dots on the left side and (b) three columns on the right side.

How we read something provides another illustration of the proximity concept. For example, we read this sentence like this, notl iket hiso rt hat. We group the letters of a given word together because there are no spaces between the letters, and we perceive words because there are spaces between each word. Here are some more examples: Cany oum akes enseo ft hiss entence? What doth es e wor dsmea n?

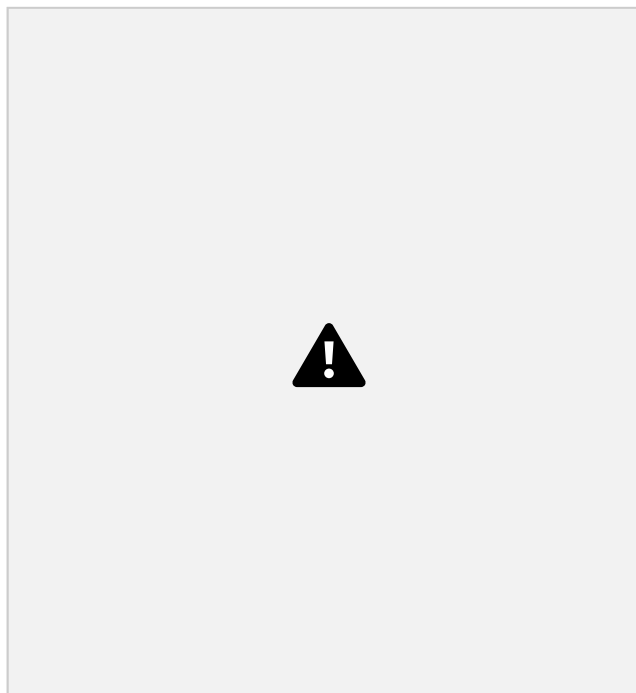
We might also use the principle of similarity to group things in our visual fields. According to this principle, things that are alike tend to be grouped together. For example, when watching a football game, we tend to group individuals based on the colors of their uniforms. When watching an offensive drive, we can get a sense of the two teams

simply by grouping along this dimension.



*Figure 12. When looking at this array of dots, we likely perceive alternating rows of colors. We are grouping these dots according to the principle of similarity.*

Two additional Gestalt principles are the law of continuity (or good continuation) and closure. The law of continuity suggests that we are more likely to perceive continuous, smooth flowing lines rather than jagged, broken lines. The principle of closure states that we organize our perceptions into complete objects rather than as a series of parts.



*Figure 13. Good continuation would suggest that we are more likely to perceive this as two overlapping lines, rather than four lines meeting in the center.*

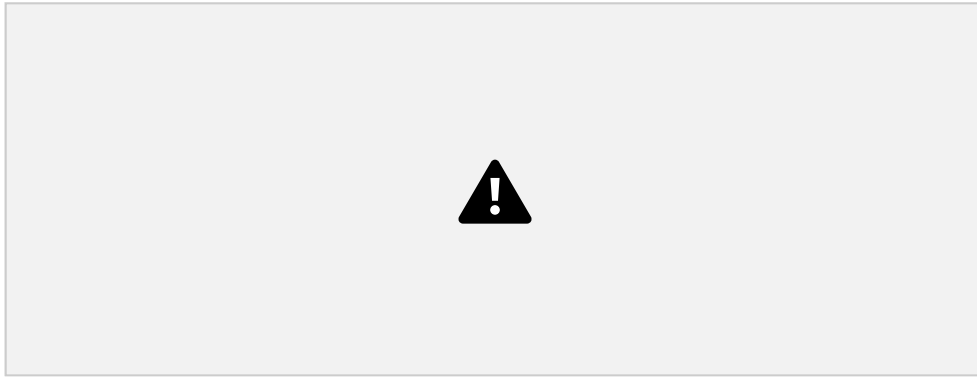


Figure 14. Closure suggests that we will perceive a complete circle and rectangle rather than a series of



[video](#)

According to Gestalt theorists, pattern perception, or our ability to discriminate among different figures and shapes, occurs by following the principles described above. You probably feel fairly certain that your perception accurately matches the real world, but this is not always the case. Our perceptions are based on perceptual hypotheses: educated guesses that we make while interpreting sensory information. These hypotheses are informed by a number of factors, including our personalities, experiences, and expectations. We use these hypotheses to generate our perceptual set. For instance, research has demonstrated that those who are given verbal priming produce a biased interpretation of complex ambiguous figures (Goolkasian & Woodbury, 2010).

## Summary

Gestalt theorists have been incredibly influential in the areas of sensation and perception. Gestalt principles such as figure-ground relationship, grouping by proximity or similarity, the law of good continuation, and closure are all used to help explain how we organize sensory information. Our perceptions are not infallible, and they can be influenced by bias, prejudice, and other factors.

## SELF CHECK QUESTIONS

### Critical Thinking Question

1. The central tenet of Gestalt psychology is that the whole is different from the sum of its parts. What does this mean in the context of perception?
2. Take a look at the following figure. How might you influence whether people see a duck or a rabbit?

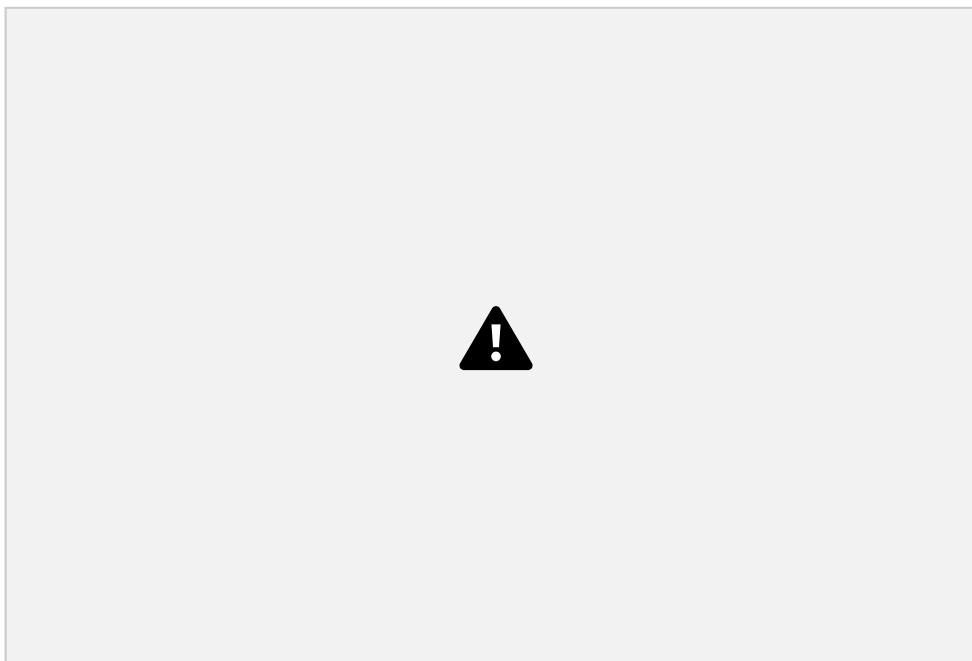


Figure 15.

### Personal Application Question

3. Have you ever listened to a song on the radio and sung along only to find out later that you have been singing the wrong lyrics? Once you found the correct lyrics, did your perception of the song change?

## ANSWERS

1. This means that perception cannot be understood completely simply by combining the parts. Rather, the relationship that exists among those parts (which would be established according to the principles described in this chapter) is important in organizing and interpreting sensory information into a perceptual set.
2. Playing on their expectations could be used to influence what they were most likely to see. For instance, telling a story about Peter Rabbit and then

presenting this image would bias perception along rabbit lines.

## GLOSSARY

- **Closure:** organizing our perceptions into complete objects rather than as a series of parts
- **Figure-ground Relationship:** segmenting our visual world into figure and ground
- **Gestalt Psychology:** field of psychology based on the idea that the whole is different from the sum of its parts
- **Good Continuation:** (also, continuity) we are more likely to perceive continuous, smooth flowing lines rather than jagged, broken lines
- **Pattern Perception:** ability to discriminate among different figures and shapes
- **Perceptual Hypothesis:** educated guess used to interpret sensory information
- **Principle of Closure:** organize perceptions into complete objects rather than as a series of parts
- **Proximity:** things that are close to one another tend to be grouped together
- **Similarity:** things that are alike tend to be grouped together

## Contributions to Cognitive Psychology “Birth”

Behaviorism’s emphasis on objectivity and focus on external behavior had pulled psychologists’ attention away from the mind for a prolonged period of time. The early work of the humanistic psychologists redirected attention to the individual human as a whole, and as a conscious and self-aware being. By the 1950s, new disciplinary perspectives in linguistics, neuroscience, and computer science were emerging, and these areas revived interest in the mind as a focus of scientific inquiry. This particular perspective has come to be known as the cognitive revolution (Miller, 2003). By 1967, Ulric Neisser published the first textbook entitled *Cognitive Psychology*, which served as a core text in cognitive psychology courses around the country (Thorne & Henley, 2005).

Although no one person is entirely responsible for starting the cognitive revolution, Noam Chomsky was very influential in the early days of this movement. Chomsky (1928–), an American linguist, was dissatisfied with the influence that behaviorism had had on psychology. He believed that psychology’s focus on behavior was short-sighted and that the field had to re incorporate mental functioning into its purview if it were to offer any meaningful contributions to understanding behavior (Miller, 2003).

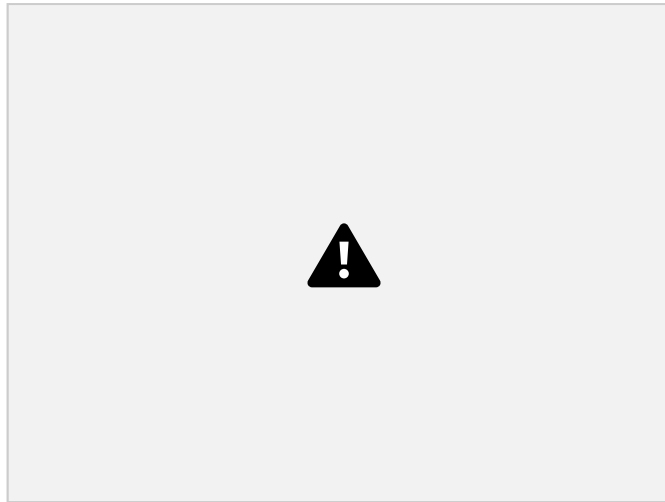


Figure 16. Noam Chomsky was very influential in beginning the cognitive revolution. In 2010, this mural honoring him was put up in Philadelphia, Pennsylvania. (credit: Robert Moran)

European psychology had never really been as influenced by behaviorism as had American psychology; and thus, the cognitive revolution helped reestablish lines of communication between European psychologists and their American counterparts. Furthermore, psychologists began to cooperate with scientists in other fields, like anthropology, linguistics, computer science, and neuroscience, among others. This interdisciplinary approach often was referred to as the cognitive sciences, and the influence and prominence of this particular perspective resonates in modern-day psychology (Miller, 2003).

## Noam Chomsky

In the middle of the 20th century, American linguist Noam Chomsky explained how some aspects of language could be innate. Prior to this time, people tended to believe that children learn language solely by imitating the adults around them. Chomsky agreed that individual words must be learned by experience, but he argued that genes could code into the brain categories and organization that form the basis of grammatical structure. We come into the world ready to distinguish different grammatical classes, like nouns and verbs and adjectives, and sensitive to the order in which words are spoken. Then, using this innate sensitivity, we quickly learn from listening to our parents about how to organize our own language <sup>[5]</sup><sup>[6]</sup> For instance, if we grow up hearing Spanish, we learn that adjectives come after nouns (*el gato amarillo*, where *gato* means “cat” and *amarillo* is “yellow”), but if we grow up hearing English, we learn that adjectives come first (“the yellow cat”). Chomsky termed this *innate sensitivity that allows infants and young children to organize the abstract categories of language* the **language acquisition device (LAD)**.

According to Chomsky’s approach, each of the many languages spoken around the world (there are between 6,000 and 8,000) is an individual example of the same underlying set of procedures that are hardwired into human brains. Each language, while unique, is just a set of variations on a small set of possible rule systems that the

brain permits language to use.

Chomsky's account proposes that children are born with a knowledge of general rules of grammar (including phoneme, morpheme, and syntactical rules) that determine how sentences are constructed.

Although there is general agreement among psychologists that babies are genetically programmed to learn language, there is still debate about Chomsky's idea that a universal grammar can account for all language learning. Evans and Levinson [7] surveyed the world's languages and found that none of the presumed underlying features of the language acquisition device were entirely universal. In their search they found languages that did not have noun or verb phrases, that did not have tenses (e.g., past, present, future), and some that did not have nouns or verbs at all, even though a basic assumption of a universal grammar is that all languages should share these features. Other psychologists believe that early experience can fully explain language acquisition, and Chomsky's language acquisition device is unnecessary. Nevertheless, Chomsky's work clearly laid out the many problems that had to be solved in order to adequately explain how children acquire language and why languages have the structures that they do.

## **Connectionism – Parallel Distributive Processing**

Connectionism was based on [principles of associationism](#), mostly claiming that elements or ideas become associated with one another through experience and that complex ideas can be explained through a set of simple rules. But connectionism further expanded these assumptions and introduced ideas like [distributed representations](#) and supervised learning and should not be confused with associationism.

### ***Connectionism and Network Models***

Network models of memory storage emphasize the role of connections between stored memories in the brain. The basis of these theories is that neural networks connect and interact to store memories by modifying the strength of the connections between neural units. In network theory, each connection is characterized by a weight value that indicates the strength of that particular connection. The stronger the connection, the easier a memory is to retrieve. Network models are based on the concept of connectionism. Connectionism is an approach in cognitive science that models mental or behavioral phenomena as the emergent processes of interconnected networks that consist of simple units. Connectionism was introduced in the 1940s by Donald Hebb, who said the famous phrase, "Cells that fire together wire together." This is the key to understanding network models: neural units that are activated together strengthen the connections between themselves.

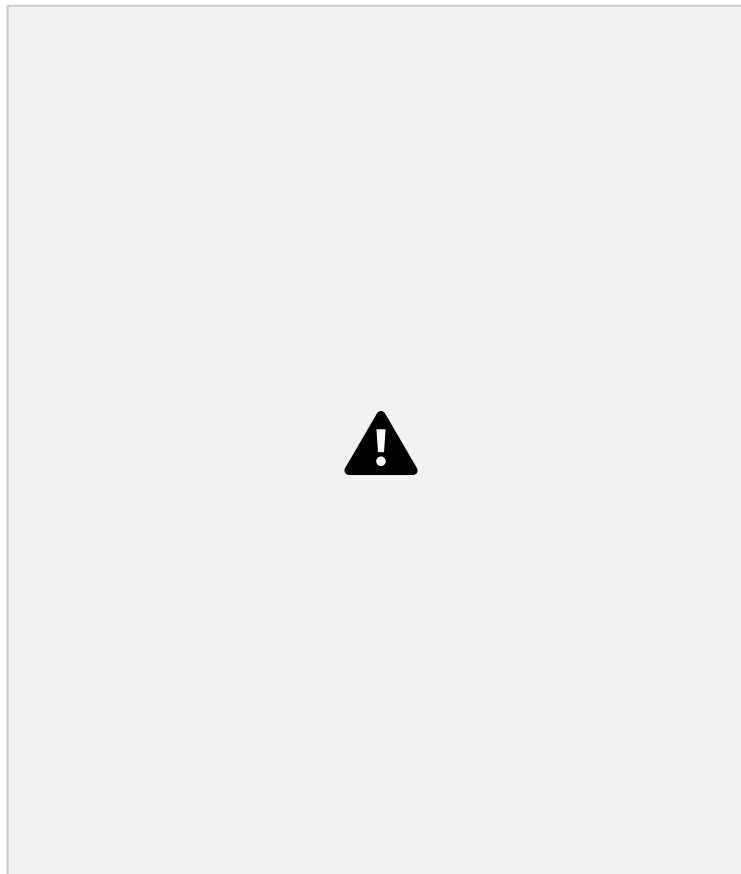
There are several types of network models in memory research. Some define the fundamental network unit as a piece of information. Others define the unit as a neuron. However, network models generally agree that memory is stored in neural networks and is strengthened or weakened based on the connections between neurons. Network

models are not the only models of memory storage, but they do have a great deal of power when it comes to explaining how learning and memory work in the brain, so they are extremely important to understand.

### ***Parallel Distributed Processing Model***

The parallel distributed processing (PDP) model is an example of a network model of memory, and it is the prevailing connectionist approach today. PDP posits that memory is made up of neural networks that interact to store information. It is more of a metaphor than an actual biological theory, but it is very useful for understanding how neurons fire and wire with each other.

Taking its metaphors from the field of computer science, this model stresses the parallel nature of neural processing. “Parallel processing” is a computing term; unlike serial processing (performing one operation at a time), parallel processing allows hundreds of operations to be completed at once—in parallel. Under PDP, neural networks are thought to work in parallel to change neural connections to store memories. This theory also states that memory is stored by modifying the strength of connections between neural units. Neurons that fire together frequently (which occurs when a particular behavior or mental process is engaged many times) have stronger connections between them. If these neurons stop interacting, the memory’s strength weakens. This model emphasizes learning and other cognitive phenomena in the creation and storage of memory.



*Figure 17. Neural connections: As neurons form connections with each other through their many dendrites, they can form complex networks. Network models propose that these connections are the basis of storing and*

retrieving memories.

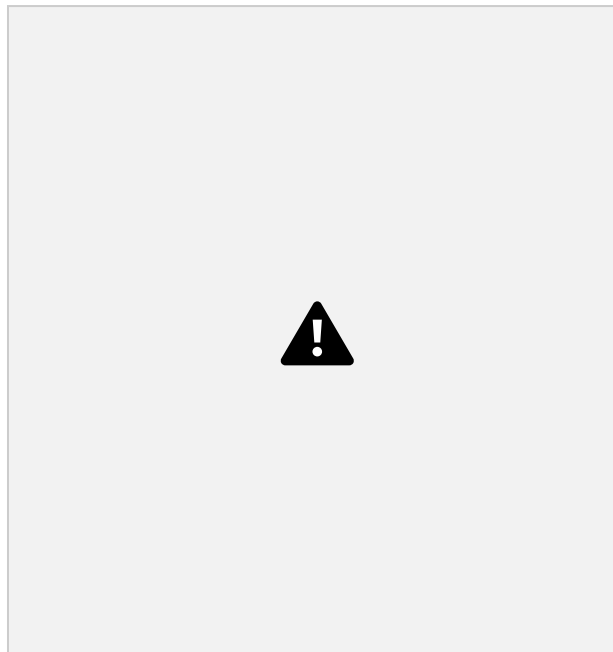
## Chapter 2 – The Brain

The picture you have in your mind of the nervous system probably includes the **brain**, the nervous tissue contained within the cranium, and the **spinal cord**, the extension of nervous tissue within the vertebral column. That suggests it is made of two organs—and you may not even think of the spinal cord as an organ—but the nervous system is a very complex structure. Within the brain, many different and separate regions are responsible for many different and separate functions. It is as if the nervous system is composed of many organs that all look similar and can only be differentiated using tools such as the microscope or electrophysiology. In comparison, it is easy to see that the stomach is different than the esophagus or the liver, so you can imagine the digestive system as a collection of specific organs.

### The Central and Peripheral Nervous Systems

The nervous system can be divided into two major regions: the central and peripheral nervous systems. The **central nervous system (CNS)** is the brain and spinal cord, and the **peripheral nervous system (PNS)** is everything else (Figure 1). The brain is contained within the cranial cavity of the skull, and the spinal cord is contained within the vertebral cavity of the vertebral column. It is a bit of an oversimplification to say that the CNS is what is inside these two cavities and the peripheral nervous system is outside of them, but that is one way to start to think about it. In actuality, there are some elements of the peripheral nervous system that are within the cranial or vertebral cavities. The peripheral nervous system is so named because it is on the periphery—meaning beyond the brain and spinal cord. Depending on different aspects of the nervous system, the dividing line between central and peripheral is not

necessarily universal.



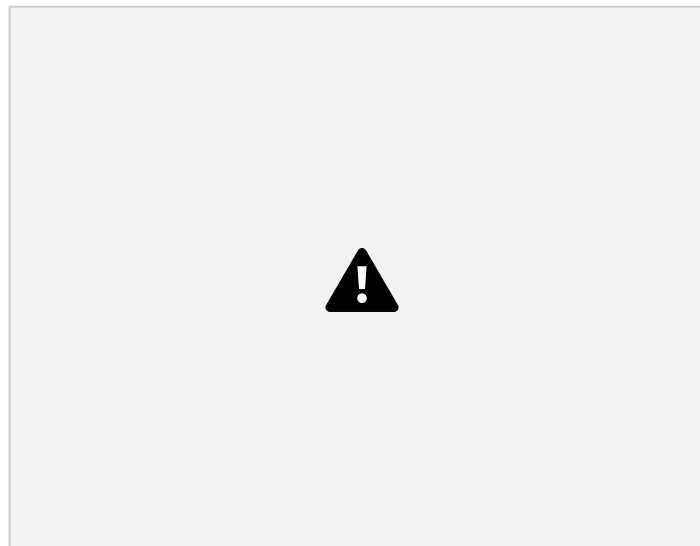
*Figure 1. Central and Peripheral Nervous System. The structures of the PNS are referred to as ganglia and nerves, which can be seen as distinct structures. The equivalent structures in the CNS are not obvious from this overall*

*perspective and are best examined in prepared tissue under the microscope.*

Nervous tissue, present in both the CNS and PNS, contains two basic types of cells: neurons and glial cells. A **glial cell** is one of a variety of cells that provide a framework of tissue that supports the neurons and their activities. The **neuron** is the more functionally important of the two, in terms of the communicative function of the nervous system. To describe the functional divisions of the nervous system, it is important to understand the structure of a neuron. Neurons are cells and therefore have a **soma**, or cell body, but they also have extensions of the cell; each extension is generally referred to as a **process**. There is one important process that every neuron has called an **axon**, which is the fiber that connects a neuron with its target. Another type of process that branches off from the soma is the **dendrite**. Dendrites are responsible for receiving most of the input from other neurons.

Looking at nervous tissue, there are regions that predominantly contain cell bodies and regions that are largely composed of just axons. These two regions within nervous system structures are often referred to as **gray matter** (the regions with many cell bodies and dendrites) or **white matter** (the regions with many axons). Figure 2 demonstrates the appearance of these regions in the brain and spinal cord. The colors ascribed to these regions are what would be seen in “fresh,” or unstained, nervous tissue. Gray matter is not necessarily gray. It can be pinkish because of blood content, or even slightly tan, depending on how long the tissue has been preserved. But white matter is white because axons are insulated by a lipid-rich substance called **myelin**. Lipids can appear as white (“fatty”) material, much like the fat on a raw piece of chicken or beef. Actually, gray matter may have that color ascribed to it because next to the white matter, it is just darker—hence, gray.

The distinction between gray matter and white matter is most often applied to central nervous tissue, which has large regions that can be seen with the unaided eye. When looking at peripheral structures, often a microscope is used and the tissue is stained with artificial colors. That is not to say that central nervous tissue cannot be stained and viewed under a microscope, but unstained tissue is most likely from the CNS—for example, a frontal section of the brain or cross section of the spinal cord.



*Figure 2. Gray Matter and White Matter. A brain removed during an autopsy, with a partial section removed,*

shows white matter surrounded by gray matter. Gray matter makes up the outer cortex of the brain. (credit: modification of work by "Suseno"/Wikimedia Commons)

Regardless of the appearance of stained or unstained tissue, the cell bodies of neurons or axons can be located in discrete anatomical structures that need to be named. Those names are specific to whether the structure is central or peripheral. A localized collection of neuron cell bodies in the CNS is referred to as a **nucleus**. In the PNS, a cluster of neuron cell bodies is referred to as a **ganglion**. Figure 3 indicates how the term nucleus has a few different meanings within anatomy and physiology. It is the center of an atom, where protons and neutrons are found; it is the center of a cell, where the DNA is found; and it is a center of some function in the CNS. There is also a potentially confusing use of the word ganglion (plural = ganglia) that has a historical explanation. In the central nervous system, there is a group of nuclei that are connected together and were once called the basal ganglia before "ganglion" became accepted as a description for a peripheral structure. Some sources refer to this group of nuclei as the "basal nuclei" to avoid confusion.

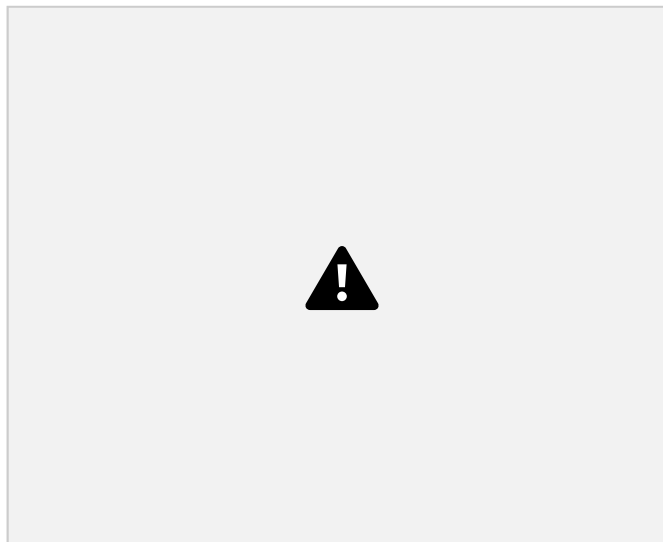
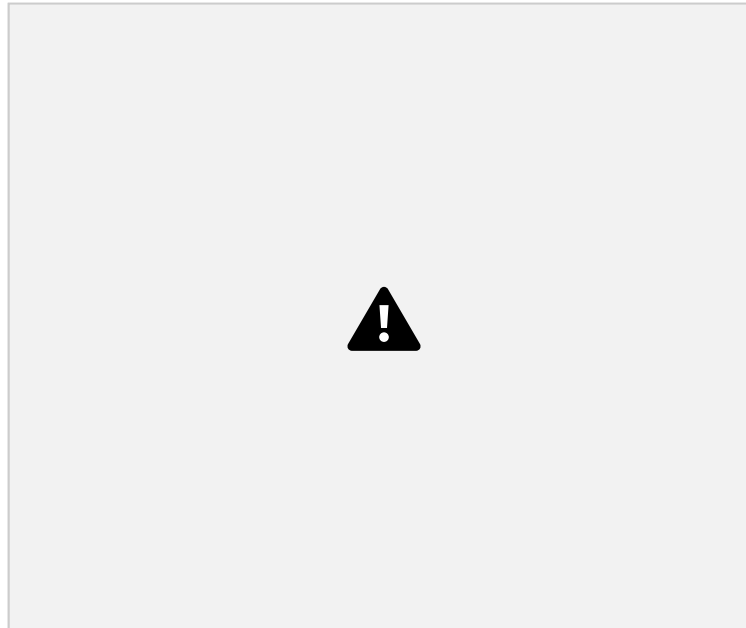


Figure 3. What Is a Nucleus? (a) The nucleus of an atom contains its protons and neutrons. (b) The nucleus of a cell is the organelle that contains DNA. (c) A nucleus in the CNS is a localized center of function with the cell bodies of several neurons, shown here circled in red. (credit c: "Was a bee"/Wikimedia Commons)

Terminology applied to bundles of axons also differs depending on location. A bundle of axons, or fibers, found in the CNS is called a **tract** whereas the same thing in the PNS would be called a **nerve**. There is an important point to make about these terms, which is that they can both be used to refer to the same bundle of axons. When those axons are in the PNS, the term is nerve, but if they are CNS, the term is tract. The most obvious example of this is the axons that project from the retina into the brain. Those axons are called the optic nerve as they leave the eye, but when they are inside the cranium, they are referred to as the optic tract. There is a specific place where the name changes, which is the optic chiasm, but they are still the same axons (Figure 4). A similar situation outside of science can be described for some roads. Imagine a road called "Broad Street" in a town called "Anyville." The road leaves Anyville and goes to the next town over, called "Hometown." When the road crosses the line between the

two towns and is in Hometown, its name changes to “Main Street.” That is the idea behind the naming of the retinal axons. In the PNS, they are called the optic nerve, and in the CNS, they are the optic tract. Table 1 helps to clarify which of these terms apply to the central or peripheral nervous systems.



*Figure 4. Optic Nerve Versus Optic Tract. This drawing of the connections of the eye to the brain shows the optic nerve extending from the eye to the chiasm, where the structure continues as the optic tract. The same axons extend from the eye to the brain through these two bundles of fibers, but the chiasm represents the border between peripheral and central.*

### **Structures of the CNS and PNS (Table 1)**

<b>CNS</b>	<b>PNS</b>
------------	------------

Group of Neuron Cell Bodies	
-----------------------------	--

(i.e., gray matter)	Nucleus Ganglion
---------------------	------------------

Bundle of Axons	
-----------------	--

(i.e., white matter)	Tract Nerve
----------------------	-------------

*Table 2.*

Visit the Nobel Prize [web site](#) to play an interactive game that demonstrates the use

of this technology and compares it with other types of imaging technologies.

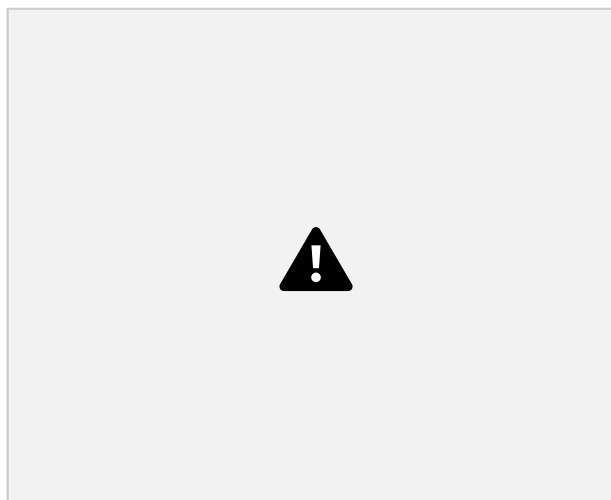
In 2003, the Nobel Prize in Physiology or Medicine was awarded to Paul C. Lauterbur and Sir

Peter Mansfield for discoveries related to magnetic resonance imaging (MRI). This is a tool to see the structures of the body (not just the nervous system) that depends on magnetic fields associated with certain atomic nuclei. The utility of this technique in the nervous system is that fat tissue and water appear as different shades between black and white. Because white matter is fatty (from myelin) and gray matter is not, they can be easily distinguished in MRI images. Visit the Nobel Prize [web site](#) to play an interactive game that demonstrates the use of this technology and compares it with other types of imaging technologies. Also, the results from an MRI session are compared with images obtained from X-ray or computed tomography. How do the imaging techniques shown in this game indicate the separation of white and gray matter compared with the freshly dissected tissue shown earlier?

## How Much of Your Brain Do You Use?

Have you ever heard the claim that humans only use 10 percent of their brains? Maybe you have seen an advertisement on a website saying that there is a secret to unlocking the full potential of your mind—as if there were 90 percent of your brain sitting idle, just waiting for you to use it. If you see an ad like that, don't click. It isn't true.

An easy way to see how much of the brain a person uses is to take measurements of brain activity while performing a task. An example of this kind of measurement is functional magnetic resonance imaging (fMRI), which generates a map of the most active areas and can be generated and presented in three dimensions (Figure 6). This procedure is different from the standard MRI technique because it is measuring changes in the tissue in time with an experimental condition or event.



*Figure 5. fMRI. This fMRI shows activation of the visual cortex in response to visual stimuli. (credit: "Superborsuk"/Wikimedia Commons)*

The underlying assumption is that active nervous tissue will have greater blood flow. By having the subject perform a visual task, activity all over the brain can be measured.

Consider this possible experiment: the subject is told to look at a screen with a black dot in the middle (a fixation point). A photograph of a face is projected on the screen away from the center. The subject has to look at the photograph and decipher what it is. The subject has been instructed to push a button if the photograph is of someone they recognize. The photograph might be of a celebrity, so the subject would press the button, or it might be of a random person unknown to the subject, so the subject would not press the button. In this task, visual sensory areas would be active, integrating areas would be active, motor areas responsible for moving the eyes would be active, and motor areas for pressing the button with a finger would be active. Those areas are distributed all around the brain and the fMRI images would show activity in more than just 10 percent of the brain (some evidence suggests that about 80 percent of the brain is using energy—based on blood flow to the tissue—during well defined tasks similar to the one suggested above). This task does not even include all of the functions the brain performs. There is no language response, the body is mostly lying still in the MRI machine, and it does not consider the autonomic functions that would be ongoing in the background.

## Lower-Level Structures of the Brain

The brain's lower-level structures consist of the brain stem, the spinal cord, and the cerebellum.

## TERMS

- **Proprioception** The sense of the position of parts of the body relative to neighbouring parts of the body.
- **Ventral** On the front side of the human body, or the corresponding surface of an animal, usually the lower surface.
- **Dorsal** With respect to, or concerning the side in which the backbone is located, or the analogous side of an invertebrate.

The brain's lower-level structures consist of the **brain stem** and spinal cord, along with the cerebellum. With the exception of the spinal cord, these structures are largely located within the hindbrain, diencephalon (or interbrain), and midbrain. These lower dorsal structures are the oldest parts of the brain, having existed for much of its evolutionary history. As such they are geared more toward basic bodily processes necessary to survival. It is the more recent layers of the brain (the forebrain) which are responsible for the higher-level **cognitive** functioning (language, reasoning) not strictly necessary to keep a body alive.

## The Hindbrain

The hindbrain, which includes the medulla oblongata, the pons, and the cerebellum, is responsible for some of the oldest and most primitive body functions. Each of these structures is described below.

### **Medulla Oblongata**

The medulla oblongata sits at the transition zone between the brain and the spinal cord. It is the first region that formally belongs to the brain (rather than the spinal cord). It is the control center for respiratory, **cardiovascular**, and digestive functions.

### **Pons**

The pons connects the medulla oblongata with the midbrain region, and also relays **signals** from the forebrain to the cerebellum. It houses the control centers for respiration and inhibitory functions. The cerebellum is attached to the dorsal side of the pons.

### **Cerebellum**

The cerebellum is a separate region of the brain located behind the medulla oblongata and pons. It is attached to the rest of the brain by three stalks (called *pedunculi*), and coordinates skeletal muscles to produce smooth, graceful motions. The cerebellum receives information from our eyes, ears, muscles, and joints about the body's current positioning (referred to as proprioception). It also receives output from the **cerebral**

**cortex** about where these body parts should be. After processing this information, the cerebellum sends motor impulses from the brain stem to the skeletal muscles so that they can move. The main function of the cerebellum is this muscle coordination. However, it is also responsible for balance and **posture**, and it assists us when we are learning a new motor skill, such as playing a sport or musical instrument. Recent research shows that apart from motor functions the cerebellum also has some role in emotional sensitivity.

### ***Human and shark brains***

The shark brain diverged on the evolutionary tree from the human brain, but both still have the “old” structures of the hindbrain and midbrain dedicated to autonomic bodily processes.

### **The Midbrain**

The midbrain is located between the hindbrain and forebrain, but it is actually part of the brain stem. It displays the same basic functional composition found in the spinal cord and the hindbrain. Ventral areas control motor function and convey motor information from the cerebral cortex. Dorsal regions of the midbrain are involved in sensory information circuits. The substantia nigra, a part of the brain that plays a role in reward, addiction, and movement (due to its high levels of dopaminergic neurons) is located in the midbrain. In Parkinson’s disease, which is characterized by a deficit of **dopamine**, death of the substantia nigra is evident.

### **The Diencephalon (“Interbrain”)**

The diencephalon is the region of the embryonic vertebrate **neural tube** that gives rise to posterior forebrain structures. In adults, the diencephalon appears at the upper end of the brain stem, situated between the **cerebrum** and the brain stem. It is home to the limbic system, which is considered the seat of emotion in the human brain. The diencephalon is made up of four distinct components: the thalamus, the subthalamus, the hypothalamus, and the epithalamus.

### ***Thalamus***

The thalamus is part of the limbic system. It consists of two lobes of grey matter along the bottom of the cerebral cortex. Because nearly all sensory information passes through the thalamus it is considered the sensory “way station” of the brain, passing information on to the cerebral cortex (which is in the forebrain). Lesions of, or stimulation to, the thalamus are associated with changes in emotional reactivity. However, the importance of this structure on the regulation of emotional behavior is not due to the activity of the thalamus itself, but to the connections between the thalamus and other limbic-system structures.

### ***Limbic system, brain stem, and spinal cord***

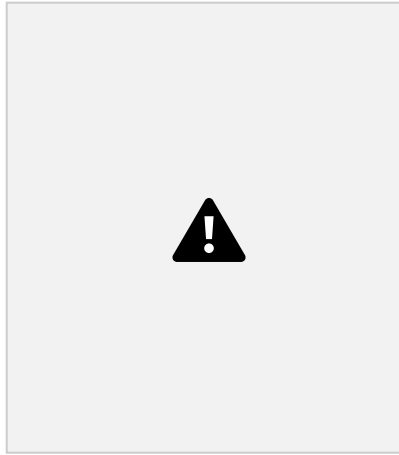


Figure 6. ([https://commons.wikimedia.org/wiki/File:Limba\\_sistemo.jpg](https://commons.wikimedia.org/wiki/File:Limba_sistemo.jpg))

### ***Hypothalamus***

The hypothalamus is a small part of the brain located just below the thalamus. Lesions of the hypothalamus interfere with motivated behaviors like sexuality, combativeness, and hunger. The hypothalamus also plays a role in emotion: parts of the hypothalamus seem to be involved in pleasure and rage, while the central part is linked to aversion, displeasure, and a tendency towards uncontrollable and loud laughing. When external **stimuli** are presented (for example, a dangerous stimuli), the hypothalamus sends signals to other limbic areas to trigger feeling states in response to the stimuli (in this case, fear).

### ***The Spinal Cord***

The spinal cord is a tail-like structure embedded in the vertebral canal of the spine. The adult spinal cord is about 40 cm long and weighs approximately 30 g. The spinal cord is attached to the underside of the medulla oblongata, and is organized to serve four distinct tasks:

1. to convey (mainly sensory) information to the brain;
2. to carry information generated in the brain to peripheral targets like skeletal muscles;
3. to control nearby organs via the **autonomic** nervous system;
4. to enable sensorimotor functions to control posture and other fundamental movements.

### **Lobes: Cerebral Hemispheres and Lobes of the Brain**

The brain is divided into two hemispheres and four lobes, each of which specializes in a different function.

## **TERMS**

- **corpus callosum** A wide, flat bundle of neural fibers beneath the cortex that connects the left and right cerebral hemispheres and facilitates interhemispheric communication.
- **lateralization** Localization of a function, such as speech, to the right or left side of the brain.
- **visuospatial** Of or pertaining to the visual perception of spatial relationships.

## **Brain Lateralization**

The brain is divided into two halves, called hemispheres. There is evidence that each brain hemisphere has its own distinct functions, a phenomenon referred to as lateralization. The left hemisphere appears to dominate the functions of speech, language processing and comprehension, and logical reasoning, while the right is **more** dominant in spatial tasks like vision-independent object recognition (such as identifying an object by touch or another nonvisual sense). However, it is easy to exaggerate the differences between the functions of the left and right hemispheres; both hemispheres are involved with most processes. Additionally, **neuroplasticity** (the ability of a brain to adapt to experience) enables the brain to compensate for damage to one hemisphere by taking on extra functions in the other half, especially in young brains.

## **Corpus Callosum**

The two hemispheres communicate with one another through the **corpus callosum**. The corpus callosum is a wide, flat bundle of neural fibers beneath the cortex that connects the left and right cerebral hemispheres and facilitates interhemispheric communication. The corpus callosum is sometimes implicated in the cause of seizures; patients with **epilepsy** sometimes undergo a corpus callosotomy, or the removal of the corpus callosum.

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### *The Lobes of The Brain*

The brain is separated into four lobes: the frontal, temporal, occipital, and parietal lobes.

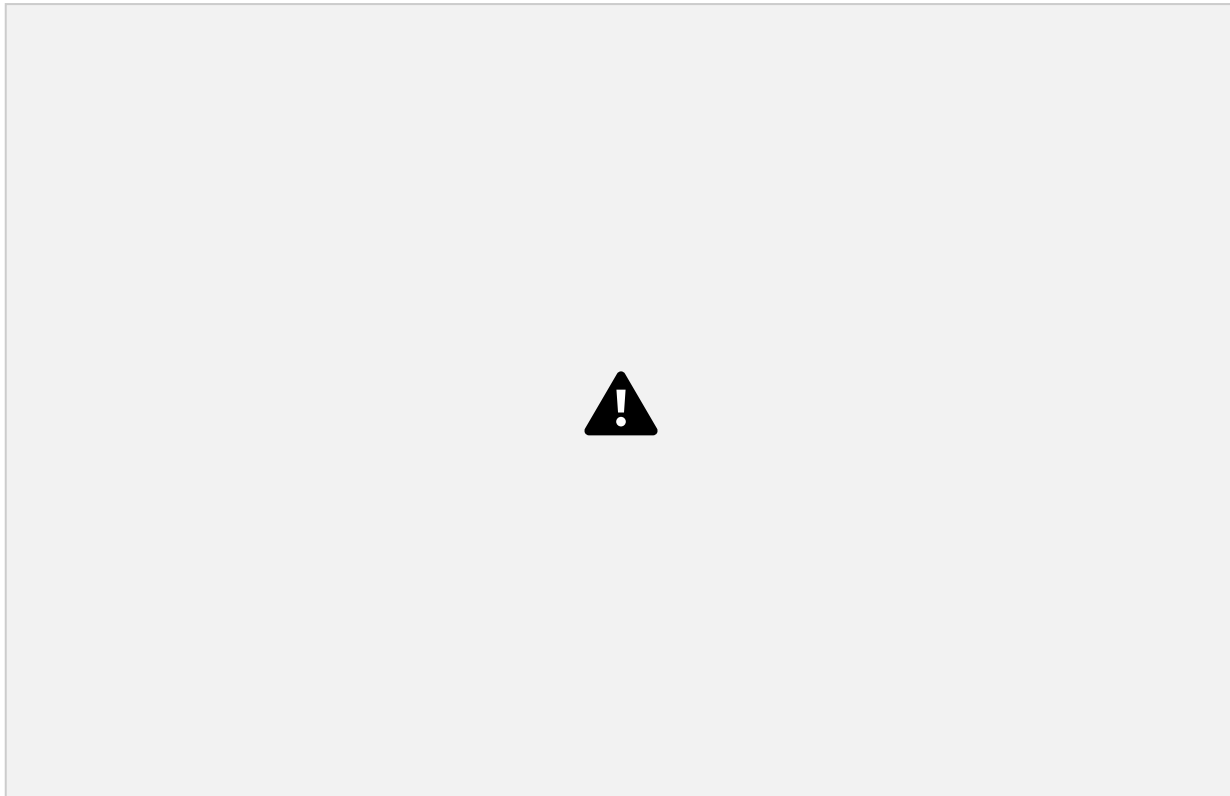


Figure 7. ([https://commons.wikimedia.org/wiki/File:Cerebrum\\_lobes.svg](https://commons.wikimedia.org/wiki/File:Cerebrum_lobes.svg))

### *Lobes of the brain*

The brain is divided into four lobes, each of which is associated with different types of mental processes. Clockwise from left: The frontal lobe is in blue, the parietal lobe in yellow, the occipital lobe in red, and the temporal lobe in green.

### *The Frontal Lobe*

The frontal lobe is associated with executive functions and motor performance. Executive functions are some of the highest-order **cognitive** processes that humans have. Examples include:

- planning and engaging in goal-directed behavior;
- recognizing future consequences of current actions;
- choosing between good and bad actions;
- overriding and suppressing socially unacceptable responses;
- determining similarities and differences between objects or situations. The frontal lobe is considered to be the moral center of the brain because it is responsible for advanced decision-making processes. It also plays an important role in retaining emotional memories derived from the **limbic system**, and modifying those **emotions** to fit socially

### *The Temporal Lobe*

The temporal lobe is associated with the retention of short- and long-term memories. It processes sensory input including auditory information, language comprehension, and naming. It also creates emotional responses and controls biological **drives** such as aggression and **sexuality**.

The temporal lobe contains the **hippocampus**, which is the memory center of the brain. The hippocampus plays a key role in the formation of emotion-laden, long-term memories based on emotional input from the **amygdala**. The left temporal lobe holds the primary auditory cortex, which is important for processing the **semantics** of speech. One specific portion of the temporal lobe, Wernicke's area, plays a key role in speech comprehension. Another portion, Broca's area, underlies the ability to produce (rather than understand) speech. Patients with damage to Wernicke's area can speak clearly but the words make no sense, while patients with damage to Broca's area will fail to form words properly and speech will be halting and slurred. These disorders are known as Wernicke's and Broca's **aphasia** respectively; an aphasia is an inability to speak.

### *Broca's and Wernicke's areas*

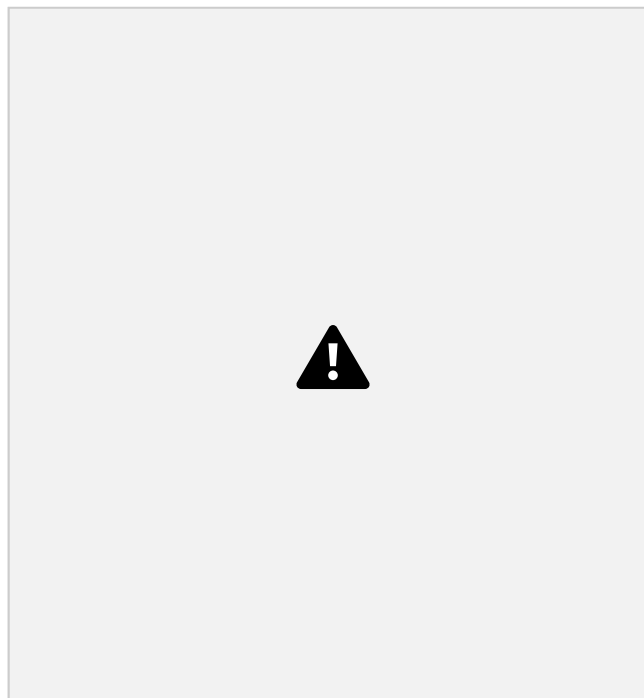


Figure 8. The locations of Broca's and Wernicke's areas in the brain.  
(<https://radiopaedia.org/cases/brocas-and-wernickes-areas-illustration>)

### *The Occipital Lobe*

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The occipital lobe contains most of the visual cortex and is the visual processing center of the brain. Cells on the posterior side of the occipital lobe are arranged as a spatial map of the retinal field. The visual cortex receives raw sensory information through sensors in the **retina** of the eyes, which is then conveyed through the optic tracts to the visual cortex. Other areas of the occipital lobe are specialized for different visual tasks, such as **visuospatial** processing, color discrimination, and **motion perception**. Damage to the primary visual cortex (located on the surface of the posterior occipital lobe) can cause blindness, due to the holes in the visual map on the surface of the cortex caused by the **lesions**.

#### *The Parietal Lobe*

The parietal lobe is associated with sensory skills. It integrates different types of sensory information and is particularly useful in spatial processing and navigation. The parietal lobe plays an important role in integrating sensory information from various parts of the body, understanding numbers and their relations, and manipulating objects. It also processes information related to the sense of touch. The parietal lobe is comprised of the somatosensory cortex and part of the visual system. The somatosensory cortex consists of a “map” of the body that processes sensory information from specific areas of the body. Several portions of the parietal lobe are important to language and visuospatial processing; the left parietal lobe is involved in symbolic functions in language and mathematics, while the right parietal lobe is specialized to process images and **interpretation** of maps (i.e., spatial relationships).

(<https://courses.lumenlearning.com/teachereducationx92x1/chapter/cerebral-hemispheres-and-lobes-of-the-brain/>)

## Limbic System and Other Brain Areas

### **Areas of the Forebrain**

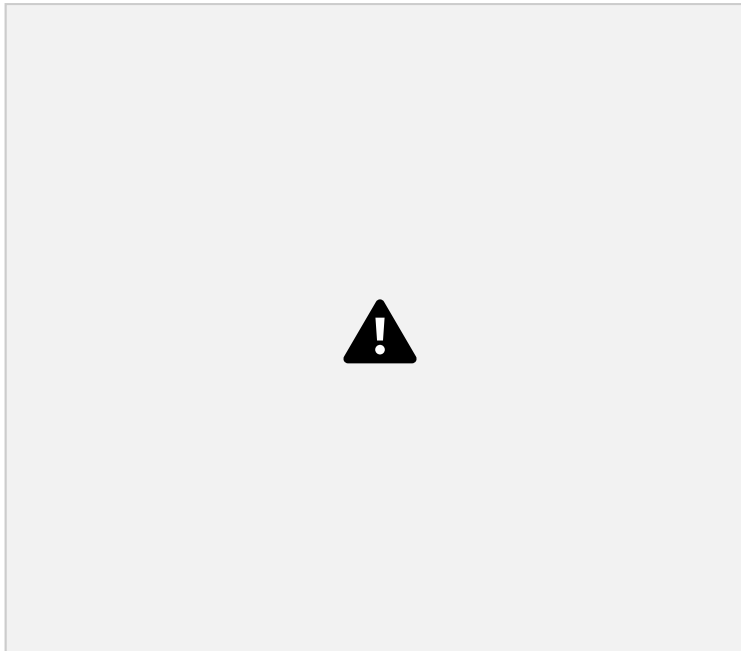
Other areas of the **forebrain** (which includes the lobes that you learned about previously), are the parts located beneath the cerebral cortex, including the thalamus and the limbic system. The **thalamus** is a sensory relay for the brain. All of our senses, with the exception of smell, are routed through the thalamus before being directed to other areas of the brain for processing (Figure 1).



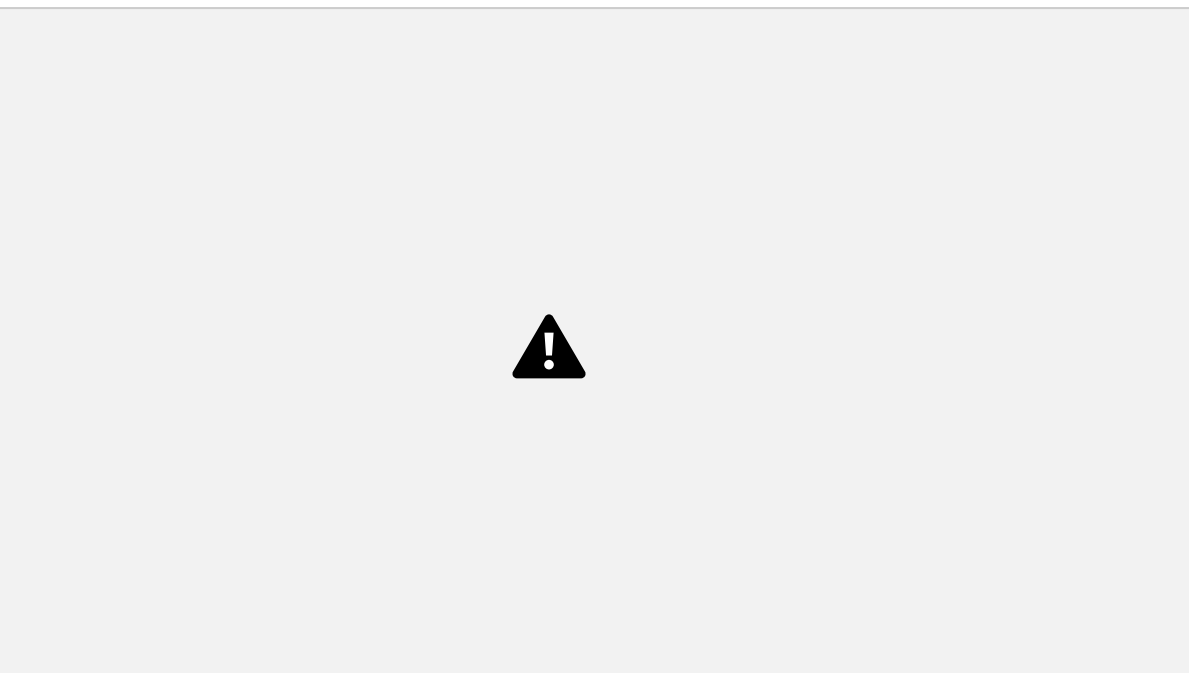
*Figure 9. The thalamus serves as the relay center of the brain where most senses are routed for processing.*

The **limbic system** is involved in processing both emotion and memory. Interestingly, the sense of smell projects directly to the limbic system; therefore, not surprisingly, smell can evoke emotional responses in ways that other sensory modalities cannot. The limbic system is made up of a number of different structures, but three of the most important are the hippocampus, the amygdala, and the hypothalamus (Figure 2). The **hippocampus** is an essential structure for learning and memory. The **amygdala** is involved in our experience of emotion and in tying emotional meaning to our memories. The **hypothalamus** regulates a number of homeostatic processes, including the regulation of body temperature, appetite, and blood pressure. The hypothalamus also serves as an interface between the nervous system and the endocrine system and in the regulation of sexual motivation and behavior.

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*Figure 10. The limbic system is involved in mediating emotional response and memory.*





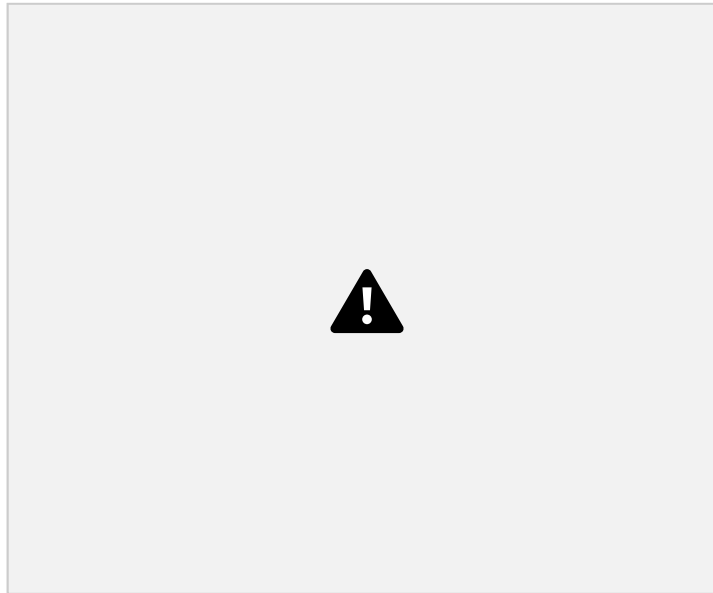
[documentary video](#)

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### Midbrain and Hindbrain Structures

The **midbrain** is comprised of structures located deep within the brain, between the forebrain and the hindbrain. The **reticular formation** is centered in the midbrain, but it actually extends up into the forebrain and down into the hindbrain. The reticular formation is important in regulating the sleep/wake cycle, arousal, alertness, and motor activity.

The **substantia nigra** (Latin for “black substance”) and the **ventral tegmental area (VTA)** are also located in the midbrain (Figure 3). Both regions contain cell bodies that produce the neurotransmitter dopamine, and both are critical for movement. Degeneration of the substantia nigra and VTA is involved in Parkinson’s disease. In addition, these structures are involved in mood, reward, and addiction (Berridge & Robinson, 1998; Gardner, 2011; George, Le Moal, & Koob, 2012).



*Figure 11. The substantia nigra and ventral tegmental area (VTA) are located in the midbrain.*

The **hindbrain** is located at the back of the head and looks like an extension of the spinal cord. It contains the medulla, pons, and cerebellum (Figure 4). The **medulla** controls the automatic processes of the autonomic nervous system, such as breathing, blood pressure, and heart rate. The word **pons** literally means “bridge,” and as the name suggests, the pons serves to connect the brain and spinal cord. It also is involved in regulating brain activity during sleep. The medulla, pons, and midbrain together are known as the brainstem.

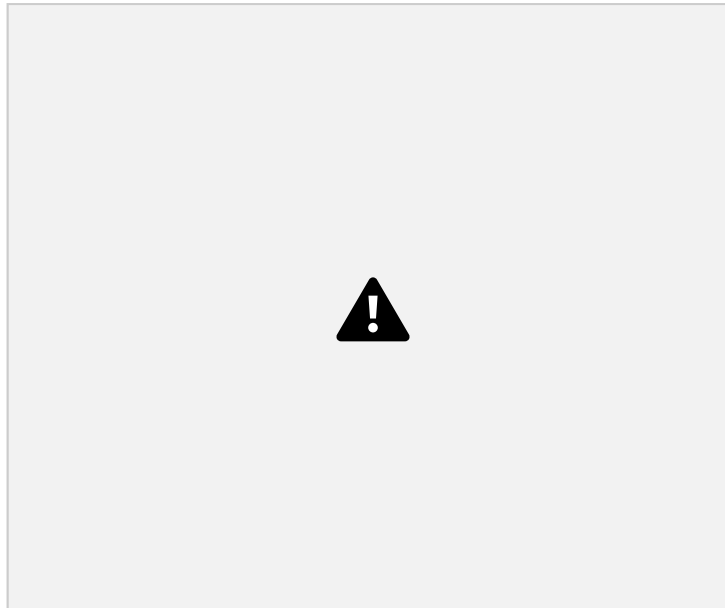


Figure 12. The pons, medulla, and cerebellum make up the hindbrain.

The **cerebellum** (Latin for “little brain”) receives messages from muscles, tendons, joints, and structures in our ear to control balance, coordination, movement, and motor skills. The cerebellum is also thought to be an important area for processing some types of memories. In particular, procedural memory, or memory involved in learning and remembering how to perform tasks, is thought to be associated with the cerebellum. Recall that H. M. was unable to form new explicit memories, but he could



## Brain and Behavior

### Pinky and the Brain:

#### ***WHAT DO YOU THINK?: BRAIN DEAD AND ON LIFE SUPPORT***

What would you do if your spouse or loved one was declared brain dead but his or her body was being kept alive by medical equipment? Whose decision should it be to

remove a feeding tube? Should medical care costs be a factor?

On February 25, 1990, a Florida woman named Terri Schiavo went into cardiac arrest, apparently triggered by a bulimic episode. She was eventually revived, but her brain had been deprived of oxygen for a long time. Brain scans indicated that there was no activity in her

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cerebral cortex, and she suffered from severe and permanent cerebral atrophy. Basically, Schiavo was in a vegetative state. Medical professionals determined that she would never again be able to move, talk, or respond in any way. To remain alive, she required a feeding tube, and there was no chance that her situation would ever improve.

On occasion, Schiavo's eyes would move, and sometimes she would groan. Despite the doctors' insistence to the contrary, her parents believed that these were signs that she was trying to communicate with them.

After 12 years, Schiavo's husband argued that his wife would not have wanted to be kept alive with no feelings, sensations, or brain activity. Her parents, however, were very much against removing her feeding tube. Eventually, the case made its way to the courts, both in the state of Florida and at the federal level. By 2005, the courts found in favor of Schiavo's husband, and the feeding tube was removed on March 18, 2005. Schiavo died 13 days later. Why did Schiavo's eyes sometimes move, and why did she groan? Although the parts of her brain that control thought, voluntary movement, and feeling were completely damaged, her brainstem was still intact. Her medulla and pons maintained her breathing and caused involuntary movements of her eyes and the occasional groans. Over the 15-year period that she was on a feeding tube, Schiavo's medical costs may have topped \$7 million (Arnst, 2003).

These questions were brought to popular conscience 25 years ago in the case of Terri Schiavo, and they persist today. In 2013, a 13-year-old girl who suffered complications after tonsil surgery was declared brain dead. There was a battle between her family, who wanted her to remain on life support, and the hospital's policies regarding persons declared brain dead. In another complicated 2013–14 case in Texas, a pregnant EMT professional declared brain dead was kept alive for weeks, despite her spouse's directives, which were based on her wishes should this situation arise. In this case, state laws designed to protect an unborn fetus came into consideration until doctors determined the fetus unviable.

Decisions surrounding the medical response to patients declared brain dead are complex. What do you think about these issues?

#### **THINK IT OVER**

You read about H. M.'s memory deficits following the bilateral removal of his hippocampus and amygdala. Have you encountered a character in a book, television program, or movie that suffered memory deficits? How was that character similar to and different from H. M.?

## GLOSSARY

- **Amygdala:** structure in the limbic system involved in our experience of emotion and tying emotional meaning to our memories
- **Cerebellum:** hindbrain structure that controls our balance, coordination, movement, and motor skills, and it is thought to be important in processing some types of memory
- **Cerebral cortex:** surface of the brain that is associated with our highest mental capabilities

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- **Forebrain:** largest part of the brain, containing the cerebral cortex, the thalamus, and the limbic system, among other structures
- **Hindbrain:** division of the brain containing the medulla, pons, and cerebellum
- **Hippocampus:** structure in the temporal lobe associated with learning and memory
- **Hypothalamus:** forebrain structure that regulates sexual motivation and behavior and a number of homeostatic processes; serves as an interface between the nervous system and the endocrine system
- **Limbic system:** collection of structures involved in processing emotion and memory
- **Medulla:** hindbrain structure that controls automated processes like breathing, blood pressure, and heart rate
- **Midbrain:** division of the brain located between the forebrain and the hindbrain; contains the reticular formation
- **Pons:** hindbrain structure that connects the brain and spinal cord; involved in regulating brain activity during sleep
- **Reticular formation:** midbrain structure important in regulating the sleep/wake cycle, arousal, alertness, and motor activity
- **Thalamus:** sensory relay for the brain
- **Ventral tegmental area (VTA):** midbrain structure where dopamine is produced: associated with mood, reward, and addiction

## Somatosensory and Motor Cortex

### Cortical Processing

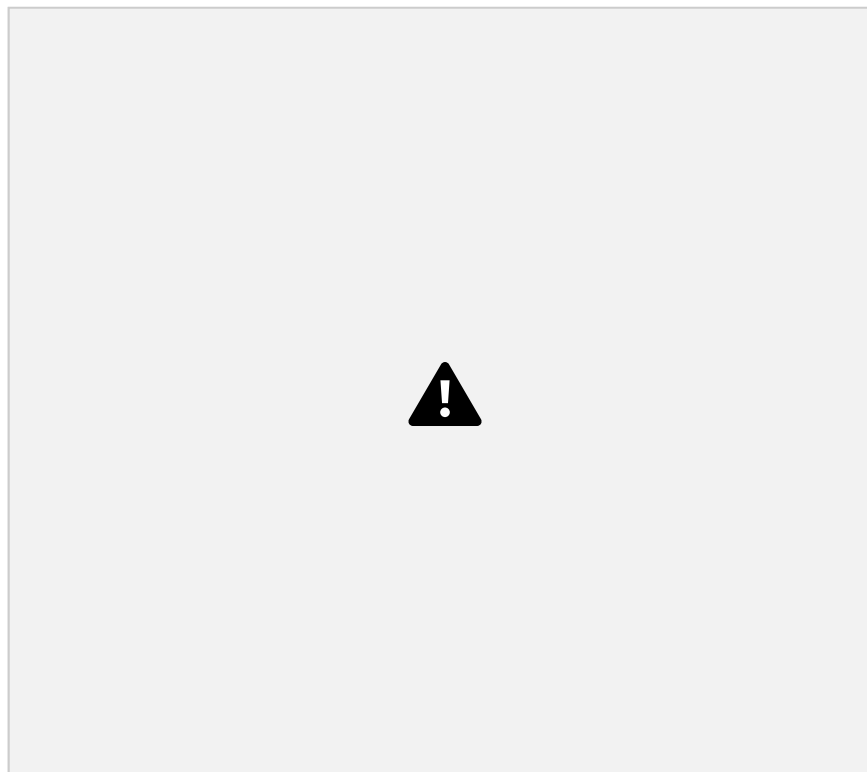
As described earlier, many of the sensory axons are positioned in the same way as their corresponding receptor cells in the body. This allows identification of the position of a stimulus on the basis of which receptor cells are sending information. The cerebral cortex also maintains this sensory topography in the particular areas of the cortex that correspond to the position of the receptor cells. The somatosensory cortex provides an example in which, in essence, the locations of the somatosensory receptors in the body are mapped onto the somatosensory cortex. This mapping is often depicted using a **sensory homunculus** (Figure 13).

The term homunculus comes from the Latin word for “little man” and refers to a map of the human body that is laid across a portion of the cerebral cortex. In the

somatosensory cortex, the external genitals, feet, and lower legs are represented on the medial face of the gyrus within the longitudinal fissure. As the gyrus curves out of the fissure and along the surface of the parietal lobe, the body map continues through the thighs, hips, trunk, shoulders, arms, and hands. The head and face are just lateral to the fingers as the gyrus approaches the lateral sulcus. The representation of the body in this topographical map is medial to lateral from the lower to upper body. It is a continuation of the topographical arrangement seen in the dorsal column system, where axons from the lower body are carried in the fasciculus gracilis, whereas axons from the upper body are carried in the fasciculus cuneatus. As the dorsal column system continues into the medial lemniscus, these relationships are maintained. Also, the head and neck axons running from the trigeminal nuclei to the thalamus run adjacent to the upper body

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fibers. The connections through the thalamus maintain topography such that the anatomic information is preserved. Note that this correspondence does not result in a perfectly miniature scale version of the body, but rather exaggerates the more sensitive areas of the body, such as the fingers and lower face. Less sensitive areas of the body, such as the shoulders and back, are mapped to smaller areas on the cortex.



*Figure 13. The Sensory Homunculus. A cartoon representation of the sensory homunculus arranged adjacent to the cortical region in which the processing takes place.*

The cortex has been described as having specific regions that are responsible for processing specific information; there is the visual cortex, somatosensory cortex, gustatory cortex, etc. However, our experience of these senses is not divided. Instead, we experience what can be referred to as a seamless percept. Our perceptions of the various sensory

modalities—though distinct in their content—are integrated by the brain so that we experience the world as a continuous whole.

In the cerebral cortex, sensory processing begins at the **primary sensory cortex**, then proceeds to an **association area**, and finally, into a **multimodal integration area**. For example, somatosensory information inputs directly into the primary somatosensory cortex in the post central gyrus of the parietal lobe where general awareness of sensation (location and type of sensation) begins. In the somatosensory association cortex details are integrated into a whole. In the highest level of association cortex details are integrated from entirely different modalities to form complete representations as we experience them.

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### Motor Responses

The defining characteristic of the somatic nervous system is that it controls skeletal muscles. Somatic senses inform the nervous system about the external environment, but the response to that is through voluntary muscle movement. The term “voluntary” suggests that there is a conscious decision to make a movement. However, some aspects of the somatic system use voluntary muscles without conscious control. One example is the ability of our breathing to switch to unconscious control while we are focused on another task. However, the muscles that are responsible for the basic process of breathing are also utilized for speech, which is entirely voluntary.

## Hemispheres

The central nervous system (CNS), consists of the brain and the spinal cord.

### The Brain

The brain is a remarkably complex organ comprised of billions of interconnected neurons and glia. It is a bilateral, or two-sided, structure that can be separated into distinct lobes. Each lobe is associated with certain types of functions, but, ultimately, all of the areas of the brain interact with one another to provide the foundation for our thoughts and behaviors.

## The Spinal Cord

It can be said that the spinal cord is what connects the brain to the outside world. Because of it, the brain can act. The spinal cord is like a relay station, but a very smart one. It not only routes messages to and from the brain, but it also has its own system of automatic processes, called reflexes.

The top of the spinal cord merges with the brain stem, where the basic processes of life are controlled, such as breathing and digestion. In the opposite direction, the spinal cord ends just below the ribs—contrary to what we might expect, it does not extend all the way to the base of the spine.

The spinal cord is functionally organized in 30 segments, corresponding with the vertebrae. Each segment is connected to a specific part of the body through the peripheral nervous system. Nerves branch out from the spine at each vertebra. Sensory nerves bring messages in;

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motor nerves send messages out to the muscles and organs. Messages travel to and from the brain through every segment.

Some sensory messages are immediately acted on by the spinal cord, without any input from the brain. Withdrawal from heat and knee jerk are two examples. When a sensory message meets certain parameters, the spinal cord initiates an automatic reflex. The signal passes from the sensory nerve to a simple processing center, which initiates a motor command. Seconds are saved, because messages don't have to go to the brain, be processed, and get sent back. In matters of survival, the spinal reflexes allow the body to react extraordinarily fast. The spinal cord is protected by bony vertebrae and cushioned in cerebrospinal fluid, but injuries still occur. When the spinal cord is damaged in a particular segment, all lower segments are cut off from the brain, causing paralysis. Therefore, the lower on the spine damage is, the fewer functions an injured individual loses.

## The Two Hemispheres

The surface of the brain, known as the **cerebral cortex**, is very uneven, characterized by a distinctive pattern of folds or bumps, known as **gyri** (singular: gyrus), and grooves, known as **sulci** (singular: sulcus), shown in Figure 1. These gyri and sulci form important landmarks that allow us to separate the brain into functional centers. The most prominent sulcus, known as the longitudinal fissure, is the deep groove that separates the brain into two halves or hemispheres: the left hemisphere and the right hemisphere.



Figure 14. The surface of the brain is covered with gyri and sulci. A deep sulcus is called a fissure, such as the longitudinal fissure that divides the brain into left and right hemispheres. (credit: modification of work by Bruce Blaus)

There is evidence of some specialization of function—referred to as **lateralization**—in each hemisphere, mainly regarding differences in language ability. Beyond that, however, the differences that have been found have been minor. What we do know is that the left hemisphere controls the right half of the body, and the right hemisphere controls the left half of the body.

The two hemispheres are connected by a thick band of neural fibers known as the **corpus callosum**, consisting of about 200 million axons. The corpus callosum allows the two

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hemispheres to communicate with each other and allows for information being processed on one side of the brain to be shared with the other side.

Normally, we are not aware of the different roles that our two hemispheres play in day-to-day functions, but there are people who come to know the capabilities and functions of their two hemispheres quite well. In some cases of severe epilepsy, doctors elect to sever the corpus callosum as a means of controlling the spread of seizures (Figure 2). While this is an effective treatment option, it results in individuals who have split brains. After surgery, these split-brain patients show a variety of interesting behaviors. For instance, a split-brain patient is unable to name a picture that is shown in the patient's left visual field because the information is only available in the largely nonverbal right hemisphere. However, they are able to recreate the picture with their left hand, which is also controlled by the right hemisphere. When the more verbal left hemisphere sees the picture that the hand drew, the patient is able to name it (assuming the left hemisphere can interpret what was drawn by the left hand).



Figure 15. (a, b) The corpus callosum connects the left and right hemispheres of the brain. (c) A scientist spreads this dissected sheep brain apart to show the corpus callosum between the hemispheres. (credit c: modification of work by



### *interactive animation*

Much of what we know about the functions of different areas of the brain comes from studying changes in the behavior and ability of individuals who have suffered damage to the brain. For example, researchers study the behavioral changes caused by strokes to learn about the functions of specific brain areas. A stroke, caused by an interruption of blood flow to a region in the brain, causes a loss of brain function in the affected region. The damage can be in a small area, and, if it is, this gives researchers the opportunity to link any resulting behavioral changes to a specific area. The types of deficits displayed after a stroke will be largely dependent on where in the brain the damage occurred.

Consider Theona, an intelligent, self-sufficient woman, who is 62 years old. Recently, she suffered a stroke in the front portion of her right hemisphere. As a result, she has great difficulty moving her left leg. (As you learned earlier, the right hemisphere controls the left side of the body; also, the brain's main motor centers are located at the front of the head, in the

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frontal lobe.) Theona has also experienced behavioral changes. For example, while in the produce section of the grocery store, she sometimes eats grapes, strawberries, and apples directly from their bins before paying for them. This behavior—which would have been very embarrassing to her before the stroke—is consistent with damage in another region in the frontal lobe—the prefrontal cortex, which is associated with judgment, reasoning, and impulse control.



[video](#)

[video](#)

## GLOSSARY

- **Corpus callosum:** thick band of neural fibers connecting the brain's two hemispheres
- **Gyrus** (plural: gyri): bump or ridge on the cerebral cortex
- **Hemisphere:** left or right half of the brain
- **Lateralization:** concept that each hemisphere of the brain is associated with specialized functions
- **Longitudinal fissure:** deep groove in the brain's cortex
- **Sulcus** (plural: sulci) depressions or grooves in the cerebral cortex

## Split-Brain Measures-severing the corpus

**callosum** Neuroplasticity, Neurogenesis, and Brain Lateralization

The control of some bodily functions, such as movement, vision, and hearing, is performed in specific areas of the cortex, and if an area is damaged, the individual will likely lose the ability to perform the corresponding function. For instance, if an infant suffers damage to facial recognition areas in the temporal lobe, it is likely that he or she will never be able to recognize faces. <sup>[1]</sup> However, the brain is not divided in an entirely

rigid way. The brain's neurons have a

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remarkable capacity to reorganize and extend themselves to carry out particular functions in response to the needs of the organism and to repair damage. As a result, the brain constantly creates new neural communication routes and rewires existing ones. **Neuroplasticity** is the *brain's ability to change its structure and function in response to experience or damage*. Neuroplasticity enables us to learn and remember new things and adjust to new experiences.

Our brains are the most “plastic” when we are young children, as it is during this time that we learn the most about our environment. And neuroplasticity continues to be observed even in adults. <sup>[2]</sup> The principles of neuroplasticity help us understand how our brains develop to reflect our experiences. For instance, accomplished musicians have a larger auditory cortex compared with the general population <sup>[3]</sup> and also require less neural activity to play their instruments than do novices. <sup>[4]</sup> These observations reflect the changes in the brain that follow our experiences.

Plasticity is also observed when damage occurs to the brain or to parts of the body that are represented in the motor and sensory cortexes. When a tumor in the left hemisphere of the brain impairs language, the right hemisphere begins to compensate to help the person recover the ability to speak. <sup>[5]</sup> And if a person loses a finger, the area of the sensory cortex that previously received information from the missing finger begins to receive input from adjacent fingers, causing the remaining digits to become more sensitive to touch. <sup>[6]</sup> Although neurons cannot repair or regenerate themselves as skin and blood vessels can, new evidence suggests that the brain can engage in **neurogenesis**, *the forming of new neurons*. <sup>[7]</sup> These new neurons originate deep in the brain and may then migrate to other brain areas where they form new connections with other neurons. <sup>[8]</sup> This leaves open the possibility that someday scientists might be able to “rebuild” damaged brains by creating drugs that help grow neurons.

## Unique Functions of the Left and Right Hemispheres Using

**Split-Brain Patients** We learned that the left hemisphere of the brain primarily senses and controls the motor movements on the right side of the body, and vice versa. This fact provides an interesting way to study brain lateralization—the idea that the left and the right hemispheres of the brain are specialized to perform different functions. Gazzaniga, Bogen, and Sperry <sup>[9]</sup> studied a patient, known as W. J., who had undergone an operation to relieve severe seizures. In this surgery, the region that normally connects the two halves of the brain and supports communication between the hemispheres, known as the corpus callosum, is severed. As a result, the patient essentially becomes a person with two separate brains. Because the left and right hemispheres are separated, each hemisphere develops a mind of its own, with its own sensations, concepts, and motivations. <sup>[10]</sup>

In their research, Gazzaniga and his colleagues tested the ability of W. J. to recognize

and respond to objects and written passages that were presented to only the left or to only the right brain hemispheres. The researchers had W. J. look straight ahead and then flashed, for a fraction of a second, a picture of a geometric shape to the left of where he was looking. By

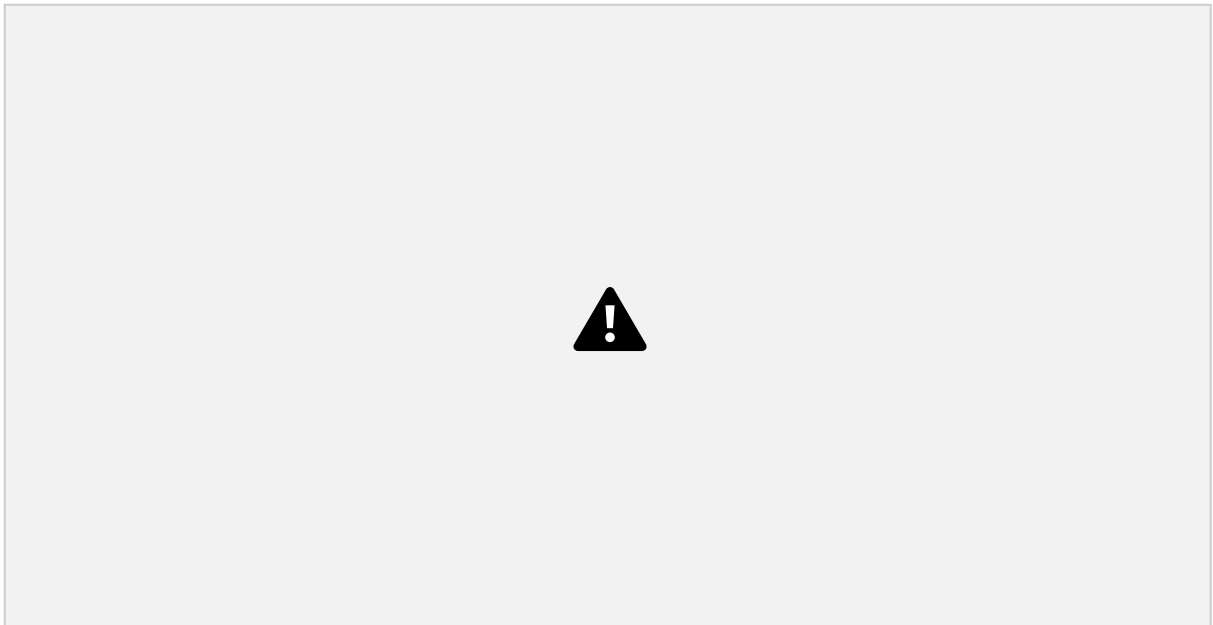
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doing so, they assured that—because the two hemispheres had been separated—the image of the shape was experienced only in the right brain hemisphere (remember that sensory input from the left side of the body is sent to the right side of the brain).

Gazzaniga and his colleagues found that W. J. was able to identify what he had been shown when he was asked to pick the object from a series of shapes, using his left hand, but that he could not do so when the object was shown in the right visual field. Conversely, W. J. could easily read written material presented in the right visual field (and thus experienced in the left hemisphere) but not when it was presented in the left visual field.

### Visual and Verbal Processing in the Split-Brain Patient

The information presented on the left side of our field of vision is transmitted to the right brain hemisphere, and vice versa. In split-brain patients, the severed corpus callosum does not permit information to be transferred between hemispheres, which allows researchers to learn about the functions of each hemisphere.



*Figure 16. In the sample on the left, the split-brain patient could not choose which image had been presented because the left hemisphere cannot process visual information. In the sample on the right, the patient could not read the passage because the right brain hemisphere cannot process language. From Flat World Knowledge, Introduction to Psychology, v1.0, [CC-BY-NC-SA](#).*

This research, and many other studies following it, demonstrated that the two brain hemispheres specialize in different abilities. In most people, the ability to speak, write, and understand language is located in the left hemisphere. This is why W. J. could read passages that were presented on the right side and thus transmitted to the left hemisphere, but could not read passages that were only experienced in the right brain

hemisphere. The left hemisphere is also better at math and at judging time and rhythm. It is also superior in coordinating the order of complex movements—for example, lip movements needed for speech. The right hemisphere has only limited verbal abilities, and yet it excels in perceptual skills. The right hemisphere is able to recognize objects, including faces, patterns, and melodies, and it can put a puzzle together or draw a picture. This is why W. J. could pick out the image

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when he saw it on the left, but not the right, visual field.

Although Gazzaniga's research demonstrated that the brain is in fact lateralized, such that the two hemispheres specialize in different activities, this does not mean that when people behave in a certain way or perform a certain activity they are using only one hemisphere of their brains at a time. That would be drastically oversimplifying the concept of brain differences. We normally use both hemispheres at the same time, and the difference between the abilities of the two hemispheres is not absolute. <sup>[11]</sup>

## Trauma

### Cortical Responses

Let's start with sensory stimuli that have been registered through receptor cells and the information relayed to the CNS along ascending pathways. In the cerebral cortex, the initial processing of sensory perception progresses to associative processing and then integration in multimodal areas of cortex. These levels of processing can lead to the incorporation of sensory perceptions into memory, but more importantly, they lead to a response. The completion of cortical processing through the primary, associative, and integrative sensory areas initiates a similar progression of motor processing, usually in different cortical areas. Whereas the sensory cortical areas are located in the occipital, temporal, and parietal lobes, motor functions are largely controlled by the frontal lobe. The most anterior regions of the frontal lobe—the prefrontal areas—are important for **executive functions**, which are those cognitive functions that lead to goal-directed behaviors. These higher cognitive processes include **working memory**, which has been called a “mental scratch pad,” that can help organize and represent information that is not in the immediate environment. The prefrontal lobe is responsible for aspects of attention, such as inhibiting distracting thoughts and actions so that a person can focus on a goal and direct behavior toward achieving that goal.

The functions of the prefrontal cortex are integral to the personality of an individual, because it is largely responsible for what a person intends to do and how they accomplish those plans. A famous case of damage to the prefrontal cortex is that of Phineas Gage, dating back to 1848. He was a railroad worker who had a metal spike impale his prefrontal cortex (Figure 1). He survived the accident, but according to second-hand accounts, his personality changed drastically. Friends described him as no longer acting like himself. Whereas he was a hardworking, amiable man before the accident, he turned into an irritable, temperamental, and lazy man after the accident. Many of the accounts of his change may have been inflated in the retelling, and some

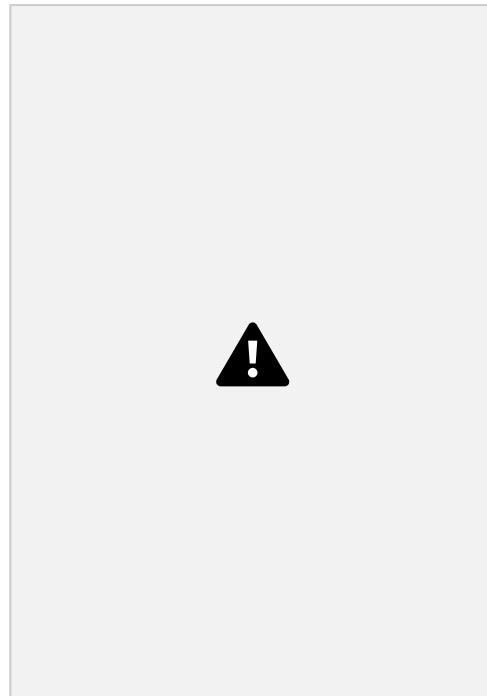
behavior was likely attributable to alcohol used as a pain medication. However, the accounts suggest that some aspects of his personality did change. Also, there is new evidence that though his life changed dramatically, he was able to become a functioning stagecoach driver, suggesting that the brain has the ability to recover even from major trauma such as this.

### ***Phineas Gage***

The victim of an accident while working on a railroad in 1848, Phineas Gage had a large iron rod impaled through the prefrontal cortex of his frontal lobe. After the accident, his personality

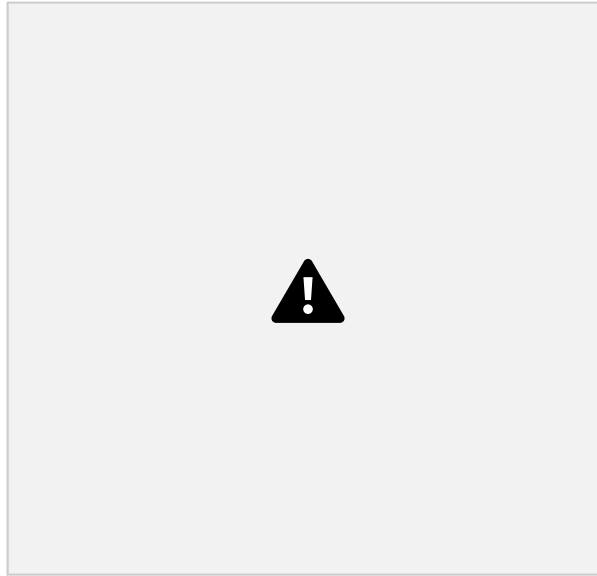
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appeared to change, but he eventually learned to cope with the trauma and lived as



a coach driver even after such a traumatic event.

*Figure 17. (credit b: John M. Harlow, MD)*



*Figure 18. Phineas Gage. The victim of an accident while working on a railroad in 1848, Phineas Gage had a large iron rod impaled through the prefrontal cortex of his frontal lobe. After the accident, his personality appeared to change, but he eventually learned to cope with the trauma and lived as a coach driver even after such a traumatic event. (credit b: John M. Harlow, MD)*

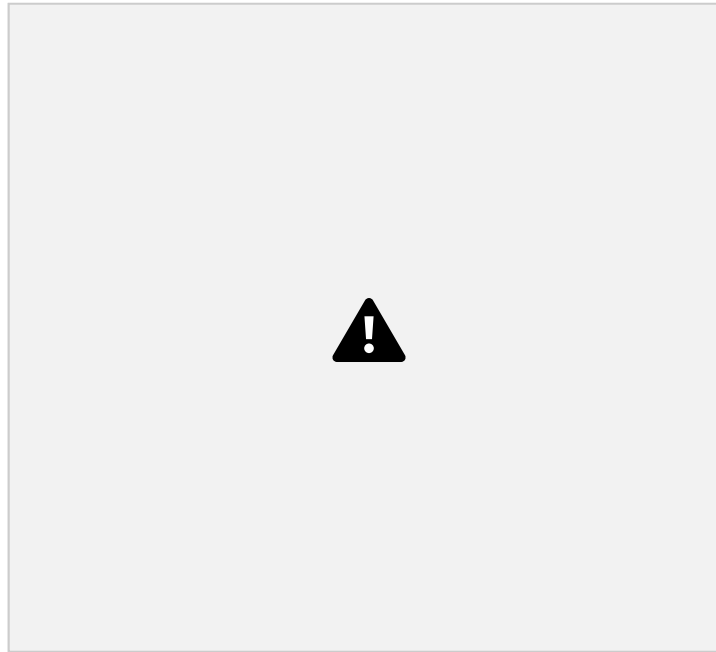
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## Chapter 3 – Methods of Research

### **A Model of Scientific Research in Psychology**

Figure 1 presents a more specific model of scientific research in psychology. The researcher (who more often than not is really a small group of researchers) formulates a research question, conducts a study designed to answer the question, analyzes the resulting data, draws conclusions about the answer to the question, and publishes the results so that they become part of the research literature. Because the research literature is one of the primary sources of new research questions, this process can be thought of as a cycle. New research leads to new questions, which lead to new

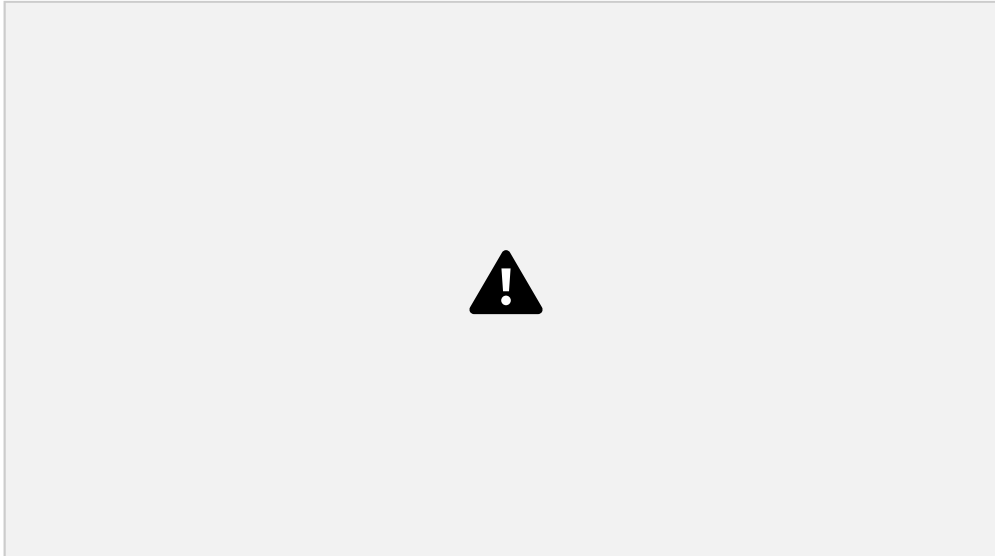
research, and so on. Figure 1 also indicates that research questions can originate outside of this cycle either with informal observations or with practical problems that need to be solved. But even in these cases, the researcher would start by checking the research literature to see if the question had already been answered and to refine it based on what previous research had already found.



*Figure 1. A Simple Model of Scientific Research in Psychology*

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The research by Mehl and his colleagues is described nicely by this model. Their question— whether women are more talkative than men—was suggested to them both by people’s stereotypes and by published claims about the relative talkativeness of women and men. When they checked the research literature, however, they found that this question had not been adequately addressed in scientific studies. They conducted a careful empirical study, analyzed the results (finding very little difference between women and men), and published their work so that it became part of the research literature. The publication of their article is not the end of the story, however, because their work suggests many new questions (about the reliability of the result, about potential cultural differences, etc.) that will likely be taken up by them and by other researchers inspired by their work.



Figure

2. Scientific research has confirmed that cell phone use impairs a variety of driving behaviors. [Indiana Stan](#) – CC BY-NC 2.0.

As another example, consider that as cell phones became more widespread during the 1990s, people began to wonder whether, and to what extent, cell phone use had a negative effect on driving. Many psychologists decided to tackle this question scientifically (Collet, Guillot, & Petit, 2010). It was clear from previously published research that engaging in a simple verbal task impairs performance on a perceptual or motor task carried out at the same time, but no one had studied the effect specifically of cell phone use on driving. Under carefully controlled conditions, these researchers compared people's driving performance while using a cell phone with their performance while not using a cell phone, both in the lab and on the road. They found that people's ability to detect road hazards, reaction time, and control of the vehicle were all impaired by cell phone use. Each new study was published and became part of the growing research literature on this topic.

## Who Conducts Scientific Research in Psychology?

Scientific research in psychology is generally conducted by people with doctoral degrees

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(usually the doctor of philosophy [PhD]) and master's degrees in psychology and related fields, often supported by research assistants with bachelor's degrees or other relevant training. Some of them work for government agencies (e.g., the National Institute of Mental Health), for nonprofit organizations (e.g., the American Cancer Society), or in the private sector (e.g., in product development). However, the majority of them are college and university faculty, who often collaborate with their graduate and undergraduate students. Although some researchers are trained and licensed as clinicians—especially those who conduct research in clinical psychology—the majority are not. Instead, they have expertise in one or more of the many other subfields of psychology: behavioral neuroscience, cognitive psychology, developmental psychology, personality psychology, social psychology, and so on. Doctoral-level researchers might

be employed to conduct research full-time or, like many college and university faculty members, to conduct research in addition to teaching classes and serving their institution and community in other ways.

Of course, people also conduct research in psychology because they enjoy the intellectual and technical challenges involved and the satisfaction of contributing to scientific knowledge of human behavior. You might find that you enjoy the process too. If so, your college or university might offer opportunities to get involved in ongoing research as either a research assistant or a participant. Of course, you might find that you do not enjoy the process of conducting scientific research in psychology. But at least you will have a better understanding of where scientific knowledge in psychology comes from, an appreciation of its strengths and limitations, and an awareness of how it can be applied to solve practical problems in psychology and everyday life.

## **The Broader Purposes of Scientific Research in Psychology**

People have always been curious about the natural world, including themselves and their behavior. (In fact, this is probably why you are studying psychology in the first place.) Science

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grew out of this natural curiosity and has become the best way to achieve detailed and accurate knowledge. Keep in mind that most of the phenomena and theories that fill psychology textbooks are the products of scientific research. In a typical introductory psychology textbook, for example, one can learn about specific cortical areas for language and perception, principles of classical and operant conditioning, biases in reasoning and judgment, and people's surprising tendency to obey authority. And scientific research continues because what we know right now only scratches the surface of what we *can* know.

Scientific research is often classified as being either basic or applied. Basic research in psychology is conducted primarily for the sake of achieving a more detailed and accurate understanding of human behavior, without necessarily trying to address any particular practical problem. The research of Mehl and his colleagues falls into this category. Applied research is conducted primarily to address some practical problem. Research on the effects of cell phone use on driving, for example, was prompted by safety concerns and has led to the enactment of laws to limit this practice. Although the distinction between basic and applied research is convenient, it is not always clear-cut. For example, basic research on sex differences in talkativeness could eventually have an effect on how marriage therapy is practiced, and applied research on the effect of cell phone use on driving could produce new insights into basic processes of perception, attention, and action.

## Key Takeaways

- Research in psychology can be described by a simple cyclical model. A research question based on the research literature leads to an empirical study, the results of which are published and become part of the research literature.
- Scientific research in psychology is conducted mainly by people with doctoral degrees in psychology and related fields, most of whom are college and university faculty members. They do so for professional and for personal reasons, as well as to contribute to scientific knowledge about human behavior.
- Basic research is conducted to learn about human behavior for its own sake, and applied research is conducted to solve some practical problem. Both are valuable, and the distinction between the two is not always clear-cut.

## Exercises

1. Practice: Find a description of an empirical study in a professional journal or in one of the scientific psychology blogs. Then write a brief description of the research in terms of the cyclical model presented here. One or two sentences for each part of the cycle should suffice.
2. Practice: Based on your own experience or on things you have already learned about psychology, list three basic research questions and three applied research questions of interest to you.

# Chapter 4 - Memory

## Memory and the Brain

### Neural Correlates of Memory Consolidation

The hippocampus, amygdala, and cerebellum play important roles in the consolidation and manipulation of memory.

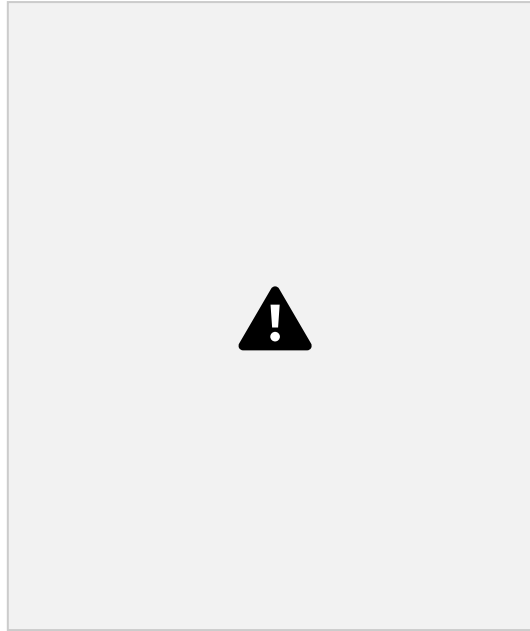
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Memory consolidation is a category of processes that stabilize a memory trace after its initial acquisition. Like encoding, consolidation affects how well a memory will be remembered after it is stored: if it is encoded and consolidated well, the memory will be easily retrieved in full detail, but if encoding or consolidation is neglected, the memory will not be retrieved or may not be accurate.

Consolidation occurs through communication between several parts of the brain, including the hippocampus, the amygdala, and the cerebellum.

### **The Hippocampus**

While psychologists and neuroscientists debate the exact role of the hippocampus, they generally agree that it plays an essential role in both the formation of new memories about experienced events and declarative memory (which handles facts and knowledge rather than motor skills). The hippocampus is critical to the formation



of memories of events and facts.

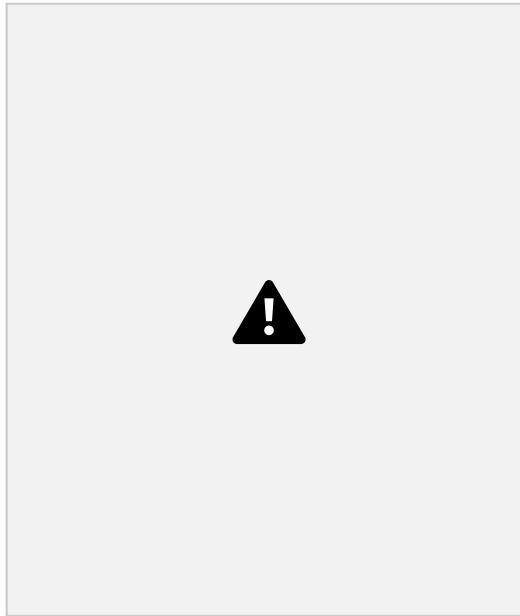
*Figure 1. The hippocampus: The hippocampus is integral in consolidating memories from short-term to long-term memory.*

Information regarding an event is not instantaneously stored in long-term memory. Instead, sensory details from the event are slowly assimilated into long-term storage over time through the process of consolidation. Some evidence supports the idea that, although these forms of memory often last a lifetime, the hippocampus ceases to play a crucial role in the retention of memory after the period of consolidation.

Damage to the hippocampus usually results in difficulties forming new memories, or anterograde amnesia, and normally also brings about problems accessing memories that were created prior to the damage, or retrograde amnesia. A famous case study that made this theory plausible is the story of a patient known as HM: After his hippocampus was removed in an effort to cure his epilepsy, he lost the ability to form memories. People with damage to the

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hippocampus may still be able to learn new skills, however, because those types of memory are non-declarative. Damage may not affect much older memories. All this contributes to the idea that the hippocampus may not be crucial in memory retention in the post-consolidation stages.

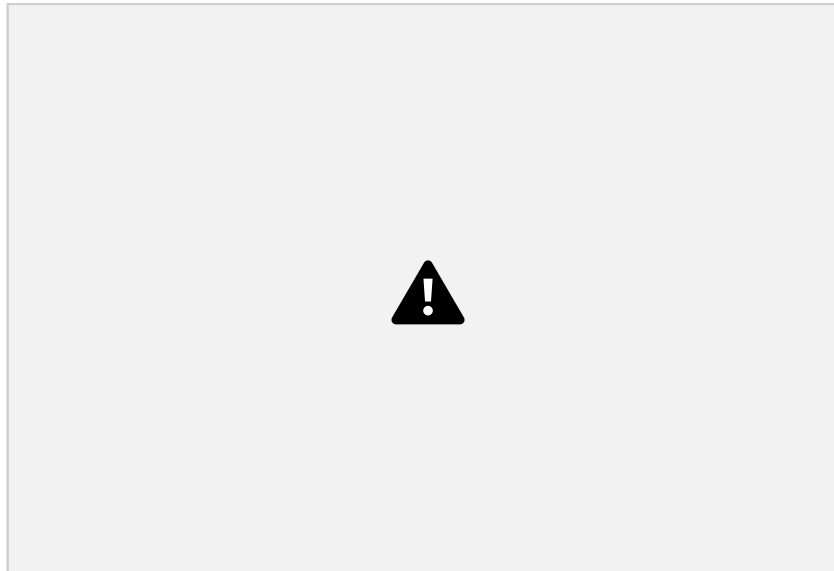


*Figure 2. The amygdala: The amygdala is involved in enhancing the consolidation of emotional memories.*

### ***The Amygdala***

The amygdala is involved in memory consolidation—specifically, in how consolidation is modulated. “Modulation” refers to the strength with which a memory is consolidated. In particular, it appears that emotional arousal following an event influences the strength of the subsequent memory. Greater emotional arousal following learning enhances a person’s retention of that stimulus.

The amygdala is involved in mediating the effects of emotional arousal on the strength of the memory of an event. Even if the amygdala is damaged, memories can still be encoded. The amygdala is most helpful in enhancing the memories of emotionally charged events, such as recalling all of the details on a day when you experienced a traumatic accident.



*Figure 3. The cerebellum: A vertical cross-section of the human cerebellum, showing the folding pattern of the cortex, and interior structures.*

### **The Cerebellum**

The cerebellum plays a role in the learning of procedural memory (i.e., routine, “practiced” skills), and motor learning, such as skills requiring coordination and fine motor control. Playing a musical instrument, driving a car, and riding a bike are examples of skills requiring procedural memory. The cerebellum is more generally involved in motor learning, and damage to it can result in problems with movement; specifically, it is thought to coordinate the timing and accuracy of movements, and to make long-term changes (learning) to improve these skills. A person with hippocampal damage might still be able to remember how to play the piano but not remember facts about their life. But a person with damage to their cerebellum would have the opposite problem: they would remember their declarative memories, but would have trouble with procedural memories like playing the piano.

### **Memory Processes**

Although the physical location of memory remains relatively unknown, it is thought to be distributed in neural networks throughout the brain.

Many areas of the brain have been associated with the processes of memory storage. Lesion studies and case studies of individuals with brain injuries have allowed scientists to determine which areas of the brain are most associated with which kinds of memory. However, the actual physical location of memories remains relatively unknown. It is theorized that memories are stored in neural networks in various parts of the brain associated with different types of memory, including short-term memory, sensory memory, and long-term memory. Keep in mind, however, that it is not sufficient to describe memory as solely dependent on specific brain regions, although there are areas and pathways that have been shown to be related to certain functions.

### **Memory Traces**

Memory traces, or *engrams*, are the physical neural changes associated with memory storage. The big question of how information and mental experiences are coded and represented in the brain remains unanswered. However, scientists have gained much

knowledge about neuronal codes from studies on neuroplasticity, the brain's capacity to change its neural connections.

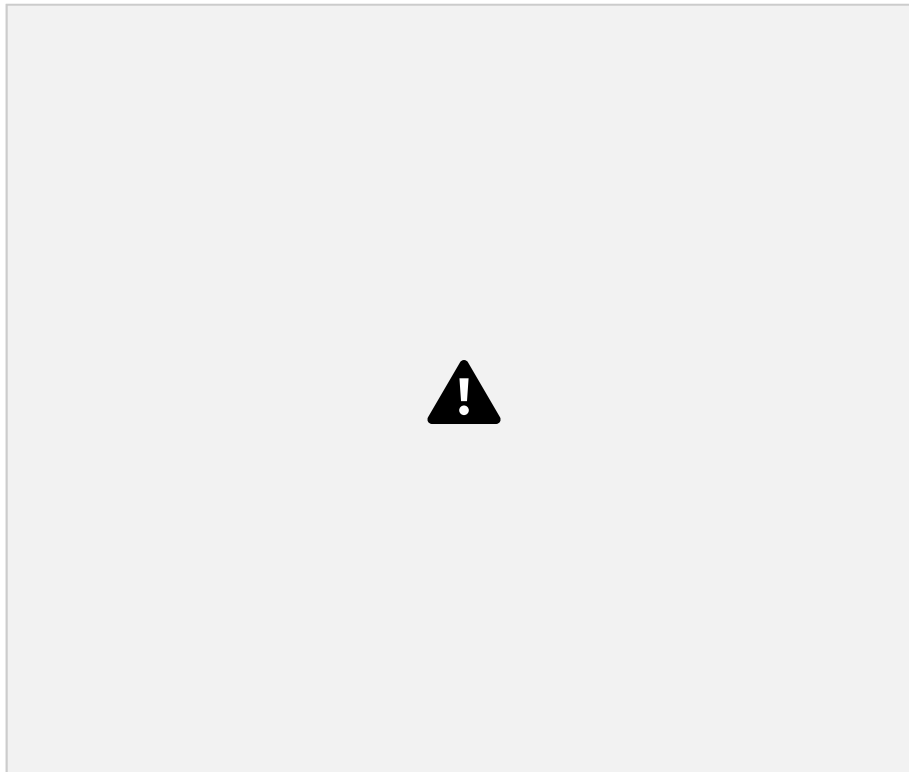
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Most of this research has been focused on simple learning and does not clearly describe changes involved in more complex examples of memory.

Encoding of working memory involves the activation of individual neurons induced by sensory input. These electric spikes continue even after the sensation stops. Encoding of episodic memory (i.e., memories of experiences) involves lasting changes in molecular structures that alter communication between neurons. Recent functional-magnetic-resonance-imaging (fMRI) studies detected working memory signals in the medial temporal lobe and the prefrontal cortex. These areas are also associated with long-term memory, suggesting a strong relationship between working memory and long-term memory.

### **Brain Areas Associated with Memory**

Imaging research and lesion studies have led scientists to conclude that certain areas of the brain may be more specialized for collecting, processing, and encoding specific types of memories. Activity in different lobes of the cerebral cortex have been linked to the formation of memories.



*Figure 4. Lobes of the cerebral cortex: While memory is created and stored throughout the brain, some regions have been shown to be associated with specific types of memory. The temporal lobe is important for sensory memory, while the frontal lobe is associated with both short- and long-term memory.*

### **Sensory Memory**

The temporal and occipital lobes are associated with sensation and are thus involved in

sensory memory. Sensory memory is the briefest form of memory, with no storage capability. Instead, it is a temporary “holding cell” for sensory information, capable of holding information for

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seconds at most before either passing it to short-term memory or letting it

disappear. **Short-Term Memory**

Short-term memory is supported by brief patterns of neural communication that are dependent on regions of the prefrontal cortex, frontal lobe, and parietal lobe. The hippocampus is essential for the consolidation of information from short-term to long-term memory; however, it does not seem to store information itself, adding mystery to the question of where memories are stored. The hippocampus receives input from different parts of the cortex and sends output to various areas of the brain. The hippocampus may be involved in changing neural connections for at least three months after information is initially processed. This area is believed to be important for spatial and declarative (i.e., fact-based) memory as well.

## Long-Term Memory

Long-term memory is maintained by stable and permanent changes in neural connections spread throughout the brain. The processes of consolidating and storing long-term memories have been particularly associated with the prefrontal cortex, cerebrum, frontal lobe, and medial temporal lobe. However, the permanent storage of long-term memories after consolidation and encoding appears to depend upon the connections between neurons, with more deeply processed memories having stronger connections.

## Three Stages of the Learning/Memory Process

Psychologists distinguish between three necessary stages in the learning and memory process: **encoding**, **storage**, and **retrieval** ([Melton, 1963](#)). Encoding is defined as the initial learning of information; storage refers to maintaining information over time; retrieval is the ability to access information when you need it. If you meet someone for the first time at a party, you need to encode her name (Lyn Goff) while you associate her name with her face. Then you need to maintain the information over time. If you see her a week later, you need to recognize her face and have it serve as a cue to retrieve her name. Any successful act of remembering requires that all three stages be intact. However, two types of errors can also occur. Forgetting is one type: you see the person you met at the party and you cannot recall her name. The other error is misremembering (false recall or false recognition): you see someone who looks like Lyn Goff and call the person by that name (false recognition of the face). Or, you might see the real Lyn Goff, recognize her face, but then call her by the name of another woman you met at the party (misrecall of her name).

Whenever forgetting or misremembering occurs, we can ask, at which stage in the learning/memory process was there a failure?—though it is often difficult to answer this question with precision. One reason for this inaccuracy is that the three stages are not

as discrete as our description implies. Rather, all three stages depend on one another. How we encode information determines how it will be stored and what cues will be effective when we try to retrieve it. And too, the act of retrieval itself also changes the way information is subsequently remembered, usually aiding later recall of the retrieved information. The central point for now is that the three stages—encoding, storage, and retrieval—affect one another,

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and are inextricably bound together.

## Encoding

Memory encoding allows an item of interest to be converted into a construct that is stored in the brain, which can later be recalled.

Memory encoding allows information to be converted into a construct that is stored in the brain indefinitely. Once it is encoded, it can be recalled from either short- or long-term memory. At a very basic level, memory encoding is like hitting “Save” on a computer file. Once a file is saved, it can be retrieved as long as the hard drive is undamaged. “Recall” refers to retrieving previously encoded information.

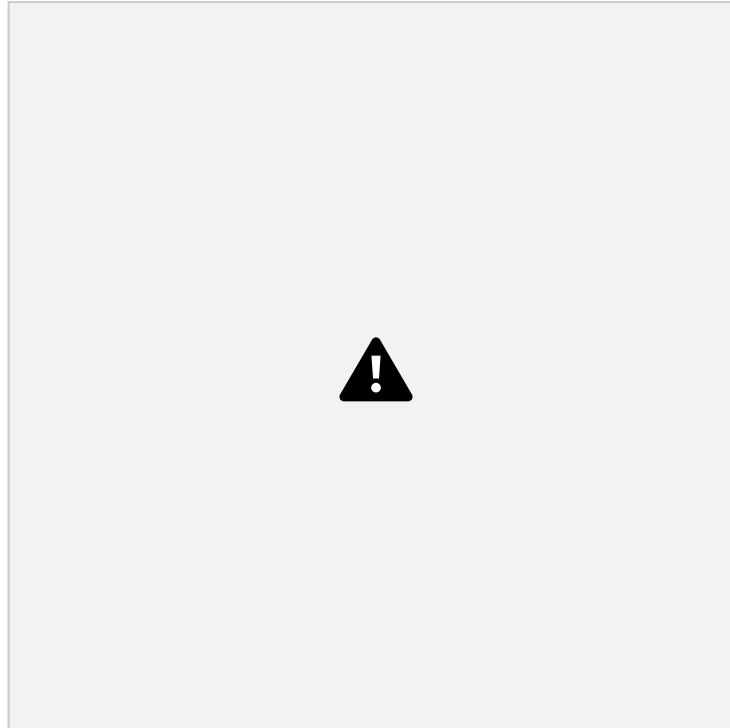
The process of encoding begins with perception, which is the identification, organization, and interpretation of any sensory information in order to understand it within the context of a particular environment. Stimuli are perceived by the senses, and related signals travel to the thalamus of the human brain, where they are synthesized into one experience. The hippocampus then analyzes this experience and decides if it is worth committing to long-term memory.

Encoding is achieved using chemicals and electric impulses within the brain. Neural pathways, or connections between neurons (brain cells), are actually formed or strengthened through a process called long-term potentiation, which alters the flow of information within the brain. In other words, as a person experiences novel events or sensations, the brain “rewires” itself in order to store those new experiences in memory.

Encoding refers to the initial experience of perceiving and learning information. Psychologists often study recall by having participants study a list of pictures or words. Encoding in these situations is fairly straightforward. However, “real life” encoding is much more challenging. When you walk across campus, for example, you encounter countless sights and sounds— friends passing by, people playing Frisbee, music in the air. The physical and mental environments are much too rich for you to encode all the happenings around you or the internal thoughts you have in response to them. So, an important first principle of encoding is that it is selective: we attend to some events in our environment and we ignore others. A second point about encoding is that it is prolific; we are always encoding the events of our lives—attending to the world, trying to understand it. Normally this presents no

problem, as our days are filled with routine occurrences, so we don't need to pay attention to everything. But if something does happen that seems strange—during your daily walk across campus, you see a giraffe—then we pay close attention and try to understand why we are seeing what we are seeing.

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*Figure 5. A giraffe in the context of a zoo or its natural habitat may register as nothing more than ordinary, but put it in another setting - in the middle of a campus or a busy city - and its level of distinctiveness increases dramatically. Distinctiveness is a key attribute to remembering events. [Image: Colin J Babb, <https://goo.gl/Cci2yl>, CC BY-SA 2.0, <https://goo.gl/jSSrcO>]*

Right after your typical walk across campus (one without the appearance of a giraffe), you would be able to remember the events reasonably well if you were asked. You could say whom you bumped into, what song was playing from a radio, and so on. However, suppose someone asked you to recall the same walk a month later. You wouldn't stand a chance. You would likely be able to recount the basics of a typical walk across campus, but not the precise details of that particular walk. Yet, if you had seen a giraffe during that walk, the event would have been fixed in your mind for a long time, probably for the rest of your life. You would tell your friends about it, and, on later occasions when you saw a giraffe, you might be reminded of the day you saw one on campus. Psychologists have long pinpointed **distinctiveness**—having an event stand out as quite different from a background of similar events—as a key to remembering events ([Hunt, 2003](#)).

In addition, when vivid memories are tinged with strong emotional content, they often seem to leave a permanent mark on us. Public tragedies, such as terrorist attacks,

often create vivid memories in those who witnessed them. But even those of us not directly involved in such events may have vivid memories of them, including memories of first hearing about them. For example, many people are able to recall their exact physical location when they first learned about the assassination or accidental death of a national figure. The term [flashbulb memory](#) was originally coined by Brown and Kulik (1977) to describe this sort of vivid memory of finding out an important piece of news. The name refers to how some memories seem to be captured in the mind like a flash photograph; because of the distinctiveness and emotionality of the news, they seem to become permanently etched in the mind with exceptional clarity

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compared to other memories.

Take a moment and think back on your own life. Is there a particular memory that seems sharper than others? A memory where you can recall unusual details, like the colors of mundane things around you, or the exact positions of surrounding objects? Although people have great confidence in flashbulb memories like these, the truth is, our objective accuracy with them is far from perfect ([Talarico & Rubin, 2003](#)). That is, even though people may have great confidence in what they recall, their memories are not as accurate (e.g., what the actual colors were; where objects were truly placed) as they tend to imagine. Nonetheless, all other things being equal, distinctive and emotional events are well-remembered.

Details do not leap perfectly from the world into a person's mind. We might say that we went to a party and remember it, but what we remember is (at best) what we encoded.

As noted above, the process of encoding is selective, and in complex situations, relatively few of many possible details are noticed and encoded. The process of encoding always involves [recoding](#)—that is, taking the information from the form it is delivered to us and then converting it in a way that we can make sense of it. For example, you might try to remember the colors of a rainbow by using the acronym ROY G BIV (red, orange, yellow, green, blue, indigo, violet). The process of recoding the colors into a name can help us to remember. However, recoding can also introduce errors—when we accidentally add information during encoding, then remember that *new* material as if it had been part of the actual experience (as discussed below).

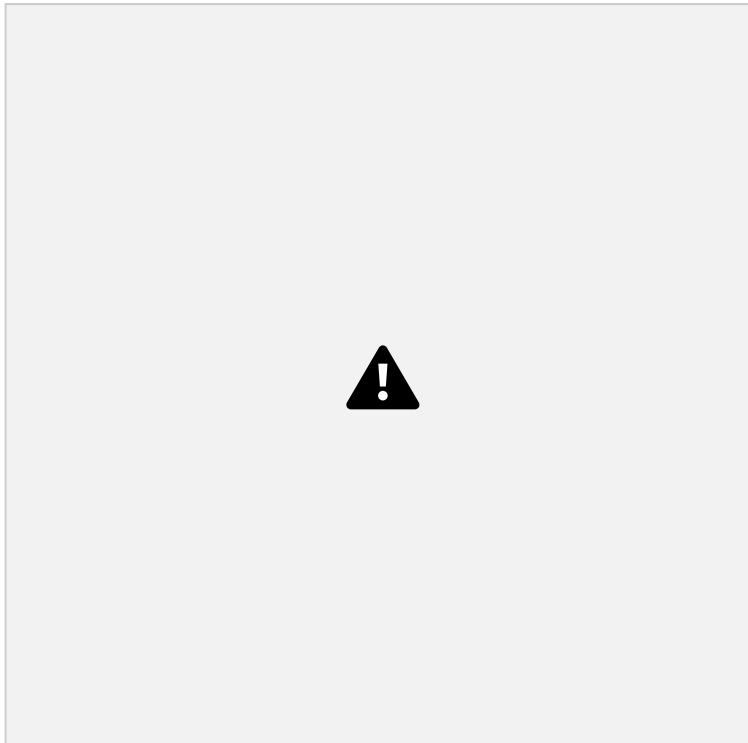


Figure 6. Although it requires more effort, using images and associations can improve the process of recoding.  
[Image: psd, <https://goo.gl/9xjcDe>, CC BY 2.0, <https://goo.gl/9uSnqN>]

Psychologists have studied many recoding strategies that can be used during study to improve

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retention. First, research advises that, as we study, we should think of the meaning of the events, and we should try to relate new events to information we already know. This helps us form associations that we can use to retrieve information later. Second, imagining events also makes them more memorable; creating vivid images out of information (even verbal information) can greatly improve later recall. Creating imagery is part of the technique Simon Reinhard uses to remember huge numbers of digits, but we can all use images to encode information more effectively. The basic concept behind good encoding strategies is to form distinctive memories (ones that stand out), and to form links or associations among memories to help later retrieval. Using study strategies such as the ones described here is challenging, but the effort is well worth the benefits of enhanced learning and retention.

We emphasized earlier that encoding is selective: people cannot encode all information they are exposed to. However, recoding can add information that was not even seen or heard during the initial encoding phase. Several of the recoding processes, like forming associations between memories, can happen without our awareness. This is one reason people can sometimes remember events that did not actually happen—because during the process of recoding, details got added. One common way of inducing false memories in the laboratory employs a word-list technique. Participants hear lists of 15 words, like *door, glass, pane, shade, ledge, sill, house, open, curtain, frame, view,*

*breeze, sash, screen, and shutter*. Later, participants are given a test in which they are shown a list of words and asked to pick out the ones they'd heard earlier. This second list contains some words from the first list (e.g., *door, pane, frame*) and some words not from the list (e.g., *arm, phone, bottle*). In this example, one of the words on the test is *window*, which—importantly—does not appear in the first list, but which is related to other words in that list. When subjects were tested, they were reasonably accurate with the studied words (*door, etc.*), recognizing them 72% of the time. However, when *window* was on the test, they falsely recognized it as having been on the list 84% of the time. The same thing happened with many other lists the authors used. This phenomenon is referred to as the DRM (for Deese Roediger-McDermott) effect. One explanation for such results is that, while students listened to items in the list, the words triggered the students to think about *window*, even though *window* was never presented. In this way, people seem to encode events that are not actually part of their experience.

Because humans are creative, we are always going beyond the information we are given: we automatically make associations and infer from them what is happening. But, as with the word association mix-up above, sometimes we make false memories from our inferences—remembering the inferences themselves as if they were actual experiences. To illustrate this, Brewer gave people sentences to remember that were designed to elicit *pragmatic inferences*. Inferences, in general, refer to instances when something is not explicitly stated, but we are still able to guess the undisclosed intention. For example, if your friend told you that she didn't want to go out to eat, you may infer that she doesn't have the money to go out, or that she's too tired. With *pragmatic inferences*, there is usually *one* particular inference you're likely to make. Consider the statement Brewer gave her participants: "The karate champion hit the cinder block." After hearing or seeing this sentence, participants who were given a memory test

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tended to remember the statement as having been, "The karate champion *broke* the cinder block." This remembered statement is not necessarily a *logical* inference (i.e., it is perfectly reasonable that a karate champion could hit a cinder block without breaking it). Nevertheless, the *pragmatic* conclusion from hearing such a sentence is that the block was likely broken. The participants remembered this inference they made while hearing the sentence in place of the actual words that were in the sentence.

Encoding—the initial registration of information—is essential in the learning and memory process. Unless an event is encoded in some fashion, it will not be successfully remembered later. However, just because an event is encoded (even if it is encoded well), there's no guarantee that it will be remembered later.

## **Storage**

Memory storage allows us to hold onto information for a very long duration of time—even a lifetime.

## Memory Storage

Memories are not stored as exact replicas of experiences; instead, they are modified and reconstructed during retrieval and recall. Memory storage is achieved through the process of encoding, through either short- or long-term memory. During the process of memory encoding, information is filtered and modified for storage in short-term memory. Information in short term memory deteriorates constantly; however, if the information is deemed important or useful, it is transferred to long-term memory for extended storage. Because long-term memories must be held for indefinite periods of time, they are stored, or consolidated, in a way that optimizes space for other memories. As a result, long-term memory can hold much more information than short-term memory, but it may not be immediately accessible. The way long-term memories are stored is similar to a digital compression. This means that information is filed in a way that takes up the least amount of space, but in the process, details of the memory may be lost and not easily recovered. Because of this consolidation process, memories are more accurate the sooner they are retrieved after being stored. As the retention interval between encoding and retrieval of the memory lengthens, the accuracy of the memory decreases.

## Short-Term Memory Storage

Short-term memory is the ability to hold information for a short duration of time (on the order of seconds). In the process of encoding, information enters the brain and can be quickly forgotten if it is not stored further in the short-term memory. George A. Miller suggested that the capacity of short-term memory storage is approximately seven items plus or minus two, but modern researchers are showing that this can vary depending on variables like the stored items' phonological properties. When several elements (such as digits, words, or pictures) are held in short-term memory simultaneously, their representations compete with each other for recall, or degrade each other. Thereby, new content gradually pushes out older content, unless

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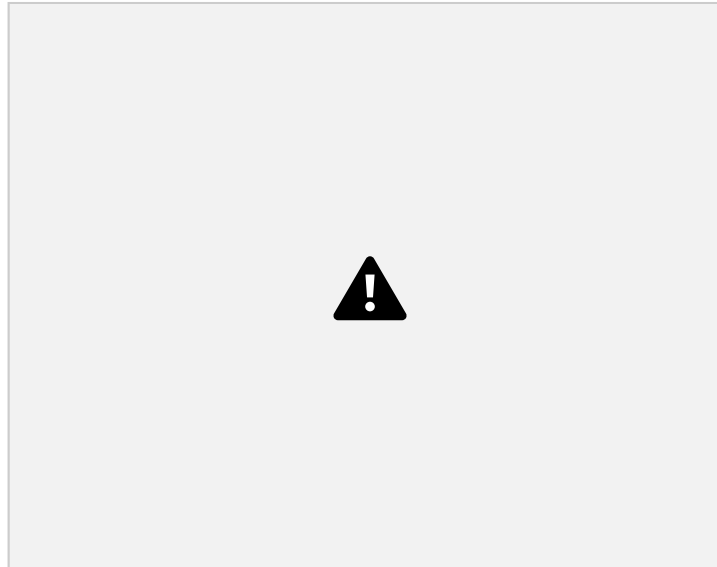
the older content is actively protected against interference by rehearsal or by directing attention to it.

Information in the short-term memory is readily accessible, but for only a short time. It continuously decays, so in the absence of rehearsal (keeping information in short-term memory by mentally repeating it) it can be forgotten.

## Long-Term Memory Storage

In contrast to short-term memory, long-term memory is the ability to hold semantic information for a prolonged period of time. Items stored in short-term memory move to long term memory through rehearsal, processing, and use. The capacity of long-term memory storage is much greater than that of short-term memory, and perhaps unlimited. However, the duration of long-term memories is not permanent; unless a memory is occasionally recalled, it may fail to be recalled on later occasions. This is known as forgetting.

Long-term memory storage can be affected by traumatic brain injury or lesions. Amnesia, a deficit in memory, can be caused by brain damage. Anterograde amnesia is the inability to store new memories; retrograde amnesia is the inability to retrieve old memories. These types of amnesia indicate that memory does have a storage process.



*Figure 7. Memory traces, or engrams, are NOT perfectly preserved recordings of past experiences. The traces are combined with current knowledge to reconstruct what we think happened in the past. [Simon Bierdwald, <https://goo.gl/JDhdCE>, CC BY-NC-SA 2.0, <https://goo.gl/jSSrcO>]*

Every experience we have changes our brains. That may seem like a bold, even strange, claim at first, but it's true. We encode each of our experiences within the structures of the nervous system, making new impressions in the process—and each of those impressions involves changes in the brain. Psychologists (and neurobiologists) say that experiences leave [memory traces](#), or [engrams](#) (the two terms are synonyms). Memories have to be stored somewhere in

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the brain, so in order to do so, the brain biochemically alters itself and its neural tissue. Just like you might write yourself a note to remind you of something, the brain “writes” a memory trace, changing its own physical composition to do so. The basic idea is that events (occurrences in our environment) create engrams through a process of [consolidation](#): the neural changes that occur after learning to create the memory trace of an experience. Although neurobiologists are concerned with exactly what neural processes change when memories are created, for psychologists, the term *memory trace* simply refers to the physical change in the nervous system (whatever that may be, exactly) that represents our experience.

Although the concept of engram or memory trace is extremely useful, we shouldn't take the term too literally. It is important to understand that memory traces are not perfect little packets of information that lie dormant in the brain, waiting to be called forward to

give an accurate report of past experience. Memory traces are not like video or audio recordings, capturing experience with great accuracy; as discussed earlier, we often have errors in our memory, which would not exist if memory traces were perfect packets of information. Thus, it is wrong to think that remembering involves simply “reading out” a faithful record of past experience. Rather, when we remember past events, we reconstruct them with the aid of our memory traces—but also with our current belief of what happened. For example, if you were trying to recall for the police who started a fight at a bar, you may not have a memory trace of who pushed whom first. However, let’s say you remember that one of the guys held the door open for you. When thinking back to the start of the fight, this knowledge (of how one guy was friendly to you) may unconsciously influence your memory of what happened in favor of the nice guy. Thus, memory is a construction of what you actually recall and what you believe happened. In a phrase, remembering is reconstructive (we reconstruct our past with the aid of memory traces) not reproductive (a perfect reproduction or recreation of the past).

## Retrieval

Memory retrieval, including recall and recognition, is the process of remembering information stored in long-term memory.

Memory retrieval is the process of remembering information stored in long-term memory. Some theorists suggest that there are three stores of memory: sensory memory, long-term memory (LTM), and short-term memory (STM). Only data that is processed through STM and encoded into LTM can later be retrieved. Overall, the mechanisms of memory are not completely understood. However, there are many theories concerning memory retrieval. There are two main types of memory retrieval: recall and recognition. In recall, the information must be retrieved from memories. In recognition, the presentation of a familiar outside stimulus provides a cue that the information has been seen before. A cue might be an object or a scene—any stimulus that reminds a person of something related. Recall may be assisted when retrieval cues are presented that enable the subject to quickly access the information in memory.

### **Patterns of Memory Retrieval**

Memory retrieval can occur in several different ways, and there are many things that can affect it, such as how long it has been since the last time you retrieved the memory, what other information you have learned in the meantime, and many other variables. For example,

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the *spacing effect* allows a person to remember something they have studied many times spaced over a longer period of time rather than all at once. The *testing effect* shows that practicing retrieval of a concept can increase the chance

of remembering it.

Some effects relate specifically to certain types of recall. There are three main types of recall studied in psychology: serial recall, free recall, and cued recall.

### **Serial Recall**

People tend to recall items or events in the order in which they occurred. This is called serial recall and can be used to help cue memories. By thinking about a string of events or even words, it is possible to use a previous memory to cue the next item in the series. Serial recall helps a person to remember the order of events in his or her life. These memories appear to exist on a continuum on which more recent events are more easily recalled. When recalling serial items presented as a list (a common occurrence in memory studies), two effects tend to surface: the *primacy effect* and the *recency effect*. The primacy effect occurs when a participant remembers words from the beginning of a list better than the words from the middle or end. The theory behind this is that the participant has had more time to rehearse these words in working memory. The recency effect occurs when a participant remembers words from the end of a list more easily, possibly since they are still available in short-term memory.

### **Free Recall**

Free recall occurs when a person must recall many items but can recall them in any order. It is another commonly studied paradigm in memory research. Like serial recall, free recall is subject to the primacy and recency effects.

### **Cued Recall**

Cues can facilitate recovery of memories that have been “lost.” In research, a process called cued recall is used to study these effects. Cued recall occurs when a person is given a list to remember and is then given cues during the testing phase to aid in the retrieval of memories. The stronger the link between the cue and the testing word, the better the participant will recall the words.

### **Interference with Memory Retrieval**

Interference occurs in memory when there is an interaction between the new material being learned and previously learned material. There are two main kinds of interference: proactive and retroactive.

### **Proactive Interference**

Proactive interference is the forgetting of information due to interference from previous knowledge in LTM. Past memories can inhibit the encoding of new memories. This is

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particularly true if they are learned in similar contexts and the new information is similar

to previous information. This is what is happening when you have trouble remembering your new phone number because your old one is stuck in your head.

## **Retroactive Interference**

Retroactive interference occurs when newly learned information interferes with the encoding or recall of previously learned information. If a participant was asked to recall a list of words, and was then immediately presented with new information, it could interfere with remembering the initial list. If you learn to use a new kind of computer and then later have to use the old model again, you might find you have forgotten how to use it. This is due to retroactive interference.

## **Retrieval Failure**

Sometimes a person is not able to retrieve a memory that they have previously encoded. This can be due to decay, a natural process that occurs when neural connections decline, like an unused muscle.

Occasionally, a person will experience a specific type of retrieval failure called tip-of-the-tongue phenomenon. This is the failure to retrieve a word from memory, combined with partial recall and the feeling that retrieval is imminent. People who experience this can often recall one or more features of the target word such as the first letter, words that sound similar, or words that have a similar meaning. While this process is not completely understood, there are two theories as to why it occurs. The first is the *direct-access perspective*, which states that the memory is not strong enough to retrieve but strong enough to trigger the state. The *inferential perspective* posits that the state occurs when the subject infers knowledge of the target word, but tries to piece together different clues about the word that are not accessible in memory.

## **Modal Model of Memory**

The three major classifications of memory that the scientific community deals with today are as follows: sensory memory, short-term memory, and long-term memory.

Information from the world around us begins to be stored by sensory memory, making it possible for this information to be accessible in the future. Short-term memory refers to the information processed by the individual in a short period of time. Working memory performs this processing. Long-term memory allows us to store information for long periods of time. This information may be retrieved consciously (explicit memory) or unconsciously (implicit memory).

## **Sensory Memory**

“Sensory memory is the capacity for briefly retaining the large amounts of information that people encounter daily” (Siegler and Alibali, 2005). There are three types of sensory memory: echoic memory, iconic memory, and haptic memory. Iconic memory retains information that is gathered through sight, echoic memory retains information gathered through auditory stimuli and haptic memory retains data acquired through touch.

