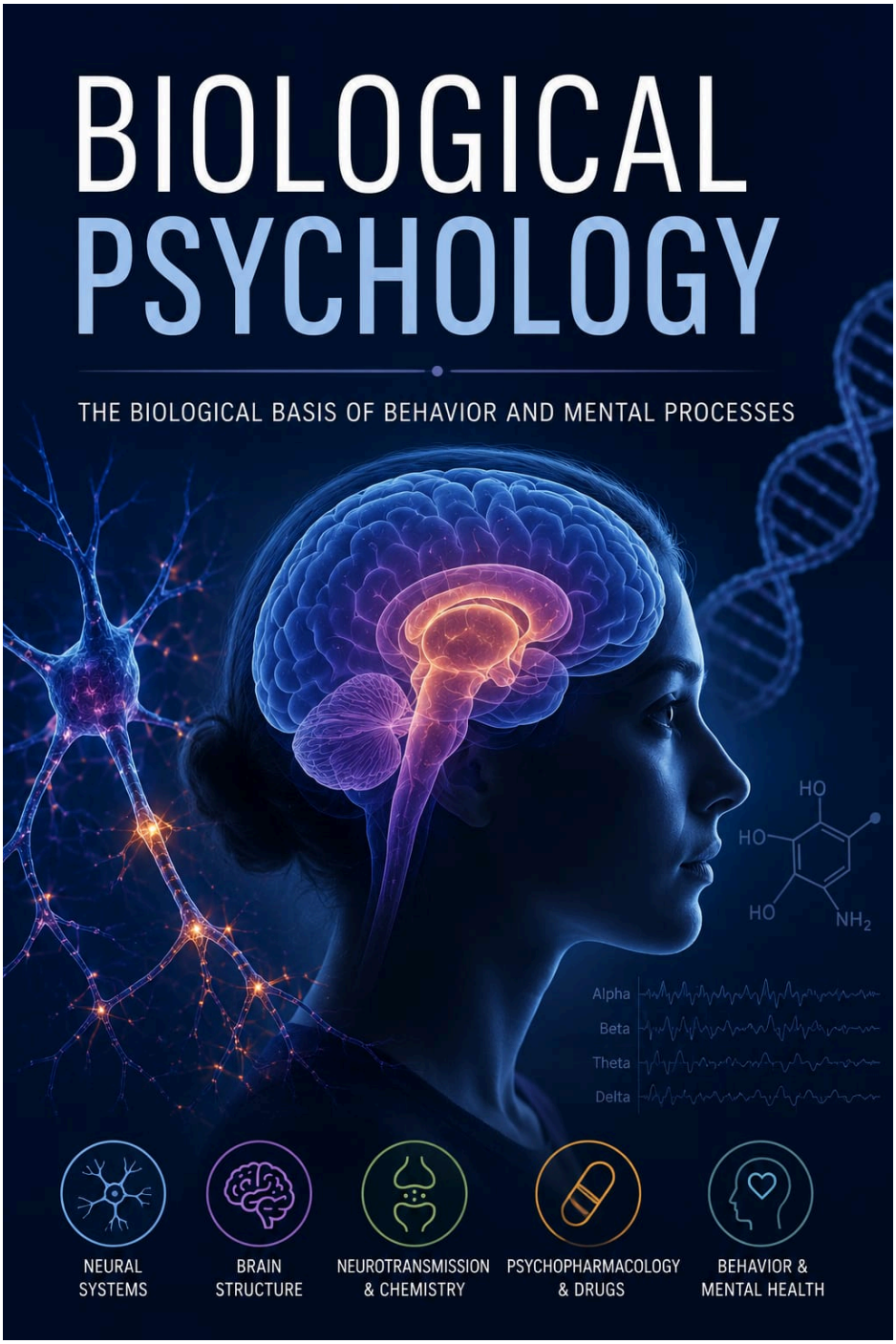
BIOLOGICAL PSYCHOLOGY (COALINGA COLLEGE ED.)



Michael Miguel
Coalinga College





Biological Psychology (Rising Scholars Ed.)

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Glossary

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About This Book

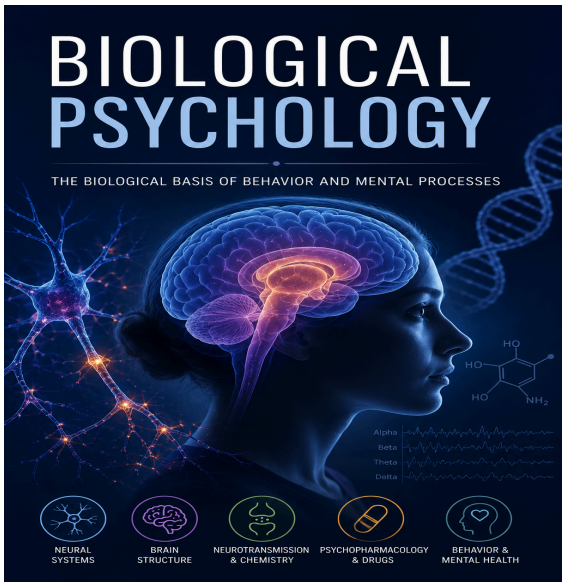
About the “From a Peer” Quotes

The “From a Peer” boxes in this book share the kinds of thoughts and experiences students often have while learning about the brain and behavior. Each quote is a composite, written with the help of AI to reflect common student experiences, so it is not the words of any real person. If one sounds familiar, that’s the point: you’re not the only one who has felt that way.

Adapted from Hove & Martinez's Biological Psychology (CC BY-NC-SA 4.0) for lower-division students at Coalinga College.

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MODULE 1: INTRODUCTION TO BIOLOGICAL PSYCHOLOGY



> **Image description:** A dark blue cover-style graphic titled “Biological Psychology: The biological basis of behavior and mental processes.” A woman’s head is shown from the side with a glowing brain inside it, surrounded by a branching neuron, a DNA double helix, a drawing of a chemical structure, and four lines of brain waves labeled alpha, beta, theta, and delta. Five icons along the bottom name the big themes of the course: neural systems, brain structure, neurotransmission and chemistry, psychopharmacology and drugs, and behavior and mental health.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Biological psychology (also called **biopsychology**) is the study of how your brain, **nervous system**, and body shape the way you think, feel, and act. It connects biology and psychology to help us understand human behavior and mental processes.

In this module, you’ll learn what the field covers, how scientists test ideas about the brain, how this research helps people in real life, why some studies use animals, and why diversity makes the science stronger. Whether you’re interested in psychology, medicine, or just curious about how your own mind works, this module sets the stage.

Learning Objectives

By the end of this module, you will be able to:

- Define biological psychology and name its major branches.
- Describe the scientific method and key research terms: hypothesis, theory, independent and dependent variables, random assignment, and replication.
- Explain the difference between basic and applied research.
- Give examples of how biological psychology helps in the real world.
- Explain why and how animals are used in research and the rules that protect them.
- Explain why diversity matters in brain science.
- Preview the topics in the rest of this book.

About This Edition

This Coalinga College edition is shared by campus students and Rising Scholars students, who take Coalinga College classes while incarcerated. It uses Central Valley examples.

What's Ahead in This Book

After this module, you'll explore the brain and nervous system; neurons; genes, development, and plasticity; vision and perception; the other senses (hearing, taste, smell, touch, and balance); consciousness, sleep, and attention; internal regulation and drive states; hormones, sex, and love; emotion and stress; learning and memory; language; psychopharmacology (how drugs affect the brain); and psychological disorders.

Unit 1.1: What Is Biological Psychology?

Unit 1.2: History and Scope of Biological Psychology

Unit 1.3: Research Methods in Biological Psychology

Unit 1.4: How Biological Psychology Helps in the Real World

Unit 1.5: Research Ethics: Protecting Animals and People

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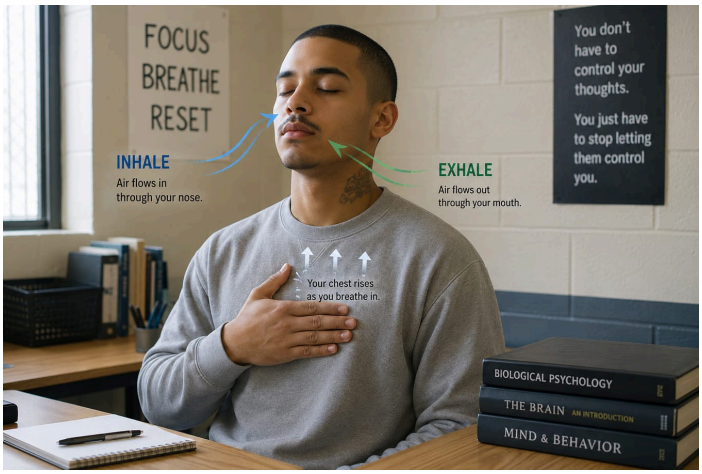
Unit 1.1: What Is Biological Psychology?

Learning Objectives

By the end of this unit, you will be able to:

- Define biological psychology.
- Describe the size of the brain's network of neurons and how much of the body's energy the brain uses.
- Give an example of how brain activity shapes an everyday experience, like breathing.

Take a moment and breathe in deeply… then breathe out. Do it one more time. The second you focused on your breathing, something changed. You noticed your chest rise and the air moving through your nose or mouth, and maybe you felt a little more grounded. The image below shows this kind of simple breathing exercise.



> **Image description:** A young man in a gray sweatshirt sits with his eyes closed and one hand on his chest, doing a breathing exercise in a quiet study room. Labels show the breath: "Inhale: air flows in through your nose" and "Exhale: air flows out through your mouth." A poster behind him reads "Focus. Breathe. Reset." and a sign says, "You don't have to control your thoughts. You just have to stop letting them control you."

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

That simple experience raises some pretty interesting questions:

- How can breathing happen on its own, yet we can also choose to control it?
- Why do we usually ignore things like the feeling of clothes on our skin until we suddenly focus on them?
- What's the point of being aware at all? Did being aware help our ancestors survive?
- And who exactly is doing the thinking and feeling inside our heads?

These questions all point us to one place: the brain.

Your thoughts, emotions, movements, memories, and even your sense of "you" all come from electrical and chemical signals flowing through your brain. Sounds wild, right? But it's true. The human brain is incredibly powerful. Some scientists call it the most complex thing we know of in the entire universe.

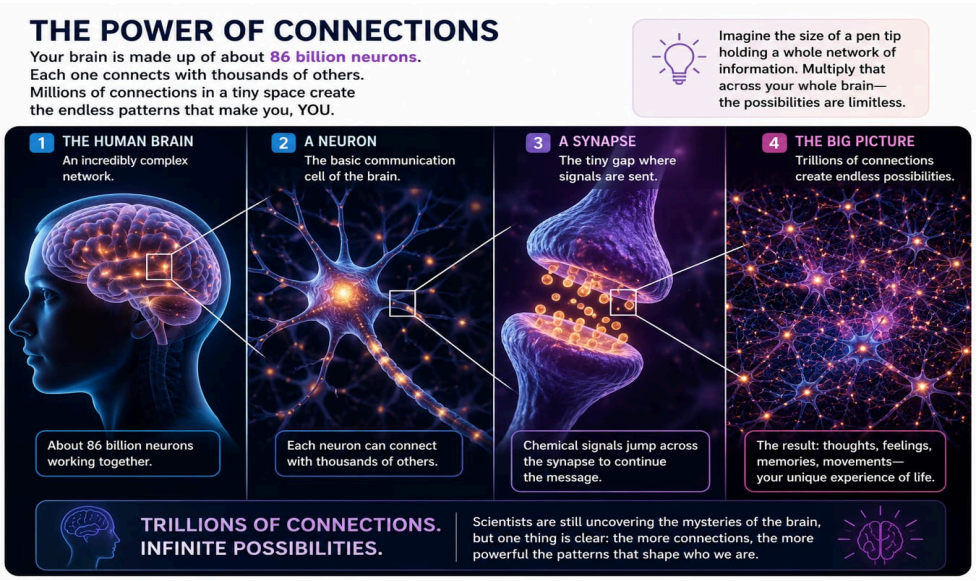
Just to give you an idea of how amazing it is: your brain is made up of about 86 billion **neurons**, the cells that send and receive messages. Each one connects with thousands of others. A piece of brain the size of a ballpoint pen tip holds hundreds of millions of these connections, and your whole brain has trillions. That means the number of possible patterns is basically limitless. And those patterns are what create your unique experience of life.

All that activity takes fuel: your brain weighs only about 3 pounds, but it uses about 20% of your body's energy, even while you're sitting still.

In Plain Words

Think of your brain like a giant phone network. Each neuron is a phone, and each connection is a line to another phone. Your brain has about 86 billion phones, each with thousands of lines. The calls going back and forth at any moment are your thoughts, feelings, and memories.

The infographic below zooms in from the whole brain to a single connection.



> **Image description:** An infographic titled "The Power of Connections" in four panels. Panel 1 shows the human brain, with about 86 billion neurons. Panel 2 shows a single neuron, which connects with thousands of others. Panel 3 shows a synapse, where chemical signals jump across a tiny gap between neurons. Panel 4, "the big picture," shows that trillions of connections create endless possibilities. A banner along the bottom reads, "Trillions of connections. Infinite possibilities."

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI); text corrected for accuracy.

Even though there's still a lot we don't understand, scientists have learned so much about how brain chemicals affect mood, how brain areas work, and how genes, life experiences, injuries, and disease shape the brain.

This is the heart of **biological psychology**: the study of how your body, especially your brain, connects to the way you think, feel, and act. In this course, we'll dig into topics like the senses, emotions, love and sex, memory, language, drugs, and mental health. By the end, you'll have a better understanding of how your brain shapes your everyday life, and maybe even how to take better care of it.

From a Peer

"I used to do breathing exercises to calm down before a big test or a job interview. Now I know my breathing was sending signals that help calm my nervous system. I had that power all along. I just didn't have the words for it."

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Unit 1.2: History and Scope of Biological Psychology

Learning Objectives

By the end of this unit, you will be able to:

- Name other terms for biological psychology and explain why Donald Hebb's 1949 book mattered.
- Identify the major branches of biological psychology and what each one studies.
- Compare the major perspectives that shape the field: the mind–body question, the evolutionary view, and the biopsychosocial view.

So what *is* biological psychology?

In short, it's the study of how the brain and body influence how we think, feel, and act. You might also hear it called **biopsychology**, **behavioral neuroscience**, or **psychobiology**. These names all point to the same big idea: our minds and behaviors are deeply connected to what's happening in our brains and nervous systems.

In this class, we use the term **biological psychology** because we're coming at things from a psychology-first point of view. That means our starting point is the mind and behavior, and we ask how our biology (like our brain, hormones, or genes) shapes our thoughts, emotions, motivations, and actions. As you'll see, the street runs both ways: our experiences can change our biology, too.

This isn't a brand-new idea. People have wondered what makes us tick for thousands of years, but the field really got going in the 1800s, when scientists started using research tools to study the mind. A major leap came in 1949, when psychologist Donald Hebb published *The Organization of Behavior*, arguing that complex thoughts and memories could be explained by brain activity. That was a game-changer.

Different Areas of Biological Psychology

Today, biological psychology is a big field with lots of branches. Here are a few:

- **Psychopharmacology**: how drugs affect the brain and behavior
- **Neuropsychology**: how brain injuries affect thinking and personality
- **Psychophysiology**: how physical signs (like heart rate or brain waves) connect to emotions or mental states
- **Psychoneuroimmunology**: how stress and hormones affect your immune system and health
- **Evolutionary psychology**: how natural selection shaped human behavior
- **Behavioral genetics**: how our genes (and environments) influence behavior
- **Cognitive neuroscience**: how brain activity supports memory, language, and problem-solving
- **Comparative psychology**: what studying animals can teach us about human behavior

Researchers often mix ideas from medicine, computer science, and even philosophy, so the field can feel overwhelming. Don't worry: you don't need to master every branch. What matters is seeing how biology and behavior connect in your own life.

Big Perspectives in the Field

Biological psychologists don't all look at behavior the same way. A few big perspectives shape how they ask questions. One of the oldest is the mind–body question: how does the mind relate to the body? The philosopher René Descartes argued for **dualism**, the idea that the mind and the physical body are different kinds of things. Modern brain research points the other way, because there are many ways to show that the mind depends on the brain (Paller & Suzuki, n.d.).

The **evolutionary perspective** asks how natural selection shaped our brains and behavior over many generations. It doesn't mean we act like robots running on rigid instincts. Our evolved tendencies interact with our environment and culture (Buss, n.d.). You'll see how evolution works in Module 4.

The **biopsychosocial** perspective, proposed by George Engel (1977), says that biological, psychological, and social factors work together in health and illness. You'll use it again when you study stress in Module 10 and psychological disorders in Module 14. All of these perspectives share one idea you'll meet again and again: biology and experience work together.

Close to Home

These branches show up in Valley jobs. A farmworker exposed to certain pesticides, an oil-field worker recovering from a head injury, and a correctional officer on rotating night shifts all raise questions neuropsychology and psychophysiology study.

Check Your Understanding

1. Name two other names for biological psychology.
2. What did Donald Hebb's 1949 book suggest?
3. Which branch studies how drugs affect the brain and behavior?
4. Which branch studies how stress and hormones affect your immune system?

The answers are in the unit you just read.

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Unit 1.3: Research Methods in Biological Psychology

Learning Objectives

By the end of this unit, you will be able to:

- Describe the steps of the scientific method, including what makes a hypothesis falsifiable.
- Identify the independent variable, dependent variable, control group, and placebo in a simple experiment.
- Explain how replication and peer review help science build knowledge we can trust.
- Compare basic and applied research.

Biological psychology might sound complex, but at its core it's based on something familiar: asking questions and testing ideas. That's the heart of the **scientific method**, a step-by-step way of exploring the world through observation and experimentation.

So how does it work?

It usually starts with a question, like *Why do some people lose their appetite when they're stressed?* From there, a researcher comes up with a possible answer, called a **hypothesis**. A good hypothesis is something you can actually test. It also has to be **falsifiable**, which means evidence could show it's wrong. That's what makes science different from opinions or beliefs. A hypothesis also fits into a bigger **theory**, a well-supported explanation that ties many findings together.

For example, say a researcher wants to test whether a certain drug reduces appetite. They'd use **random assignment** (like a coin flip) to split people into two groups. The **experimental group** gets the drug, and the **control group** gets a fake pill called a **placebo**. The drug is the **independent variable** (what the researcher changes), and how much people eat is the **dependent variable** (what gets measured). If the drug group eats less, that supports the hypothesis. If not, that's part of science, too. Even when you're wrong, you learn something.

In Plain Words

Say you want to know whether coffee helps people stay alert on a night shift. Coffee is what you change: the independent variable. How alert workers are, measured with a quick reaction-time test, is what you measure: the dependent variable. You'd flip a coin to decide who gets real coffee and who gets decaf that looks the same (random assignment and a placebo). That way, the only real difference between the groups is the caffeine.

Scientists then share their results so others can try the same study again, called **replication**, to see whether the results hold up. That's how science builds knowledge we can trust.

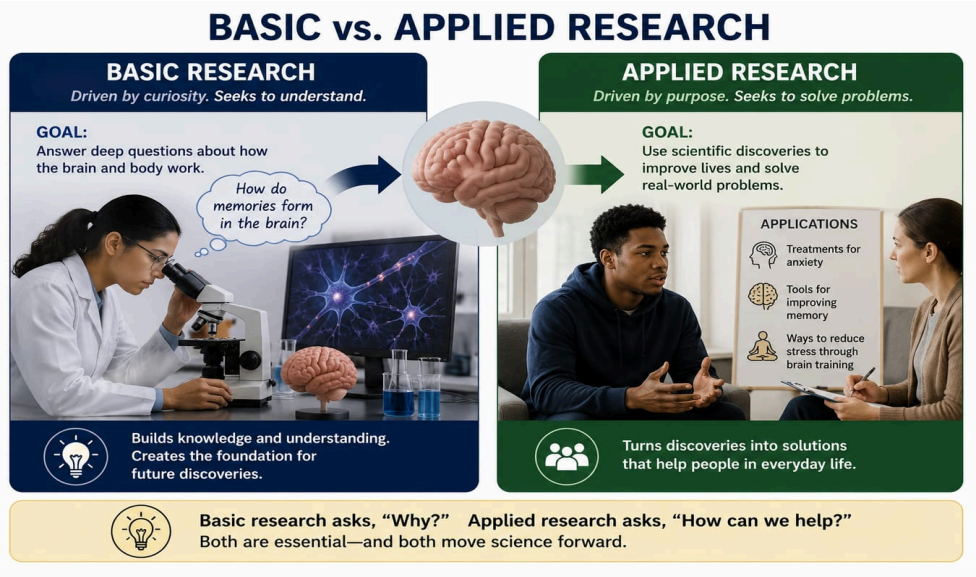
Before a study is published in a scientific journal, it usually goes through **peer review**. Several other scientists, usually anonymous, check the study's reasoning, methods, ethics, and conclusions and look for flaws. The journal's editor then decides to publish it as is (which is rare), ask for changes, or reject it. Peer review is an important quality check, but it isn't perfect: published studies are sometimes later found to be wrong and withdrawn, which is one more reason replication matters (Spielman et al., 2020a).

Basic vs. Applied Research

You'll also hear about two types of research:

- **Basic research** is about curiosity. It asks deep questions like *How do memories form in the brain?* It might not have an immediate use, but it builds the foundation for future discoveries.
- **Applied research** uses those discoveries to solve real-world problems. Think: treatments for anxiety, tools for improving memory, or ways to reduce stress through brain training.

The infographic below compares the two.



> **Image description:** A two-panel infographic titled "Basic vs. Applied Research." On the left, a scientist looks into a microscope and asks, "How do memories form in the brain?" This panel shows basic research, driven by curiosity. On the right, a counselor meets with a client, with examples of applied research: treatments for anxiety, tools for improving memory, and ways to reduce stress. The footer reads: "Basic research asks Why? Applied research asks How can we help?"

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Both types matter, and they feed each other: basic research fuels applied discoveries, and applied research raises new questions.

Key Takeaways

- Science means asking testable questions and following the evidence.
- Experiments compare an experimental group with a control group, and replication checks the results.
- Basic research asks why; applied research asks how we can help.

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Unit 1.4: How Biological Psychology Helps in the Real World

Learning Objectives

By the end of this unit, you will be able to:

- Give examples of treatments that came from brain research, such as TMS, brain implants, and brain–computer interfaces.
- Describe how brain science and artificial intelligence (AI) help each other.
- Explain how brain science is changing policies on addiction and mental health care.

You might be wondering, “Okay, learning about the brain is cool… but how does it actually matter in real life?” Great question.

Biological psychology isn’t just theory. It helps people heal, improves mental health care, guides new technology, and shapes better policies.

Healing the Brain

Millions of people live with brain injuries or mental health challenges. Brain research has led to:

- **New medications** that target specific brain chemicals
- **Brain stimulation** like **transcranial magnetic stimulation (TMS)**, which uses magnetic pulses and can ease depression
- **Brain implants** (deep brain stimulation) that reduce symptoms of Parkinson’s disease
- **Brain–computer interfaces** that let some people with paralysis control a wheelchair or robotic arm just by thinking

This is science helping people regain movement, communication, and hope.

Close to Home

Valley fever is caused by a fungus in Central Valley soil. When farming, construction, or wind stirs up dust, people can breathe in its spores. Most people have mild symptoms or none, but in rare cases the infection reaches the lining of the brain (meningitis), and brain science helps doctors spot and treat it.

Building Better AI

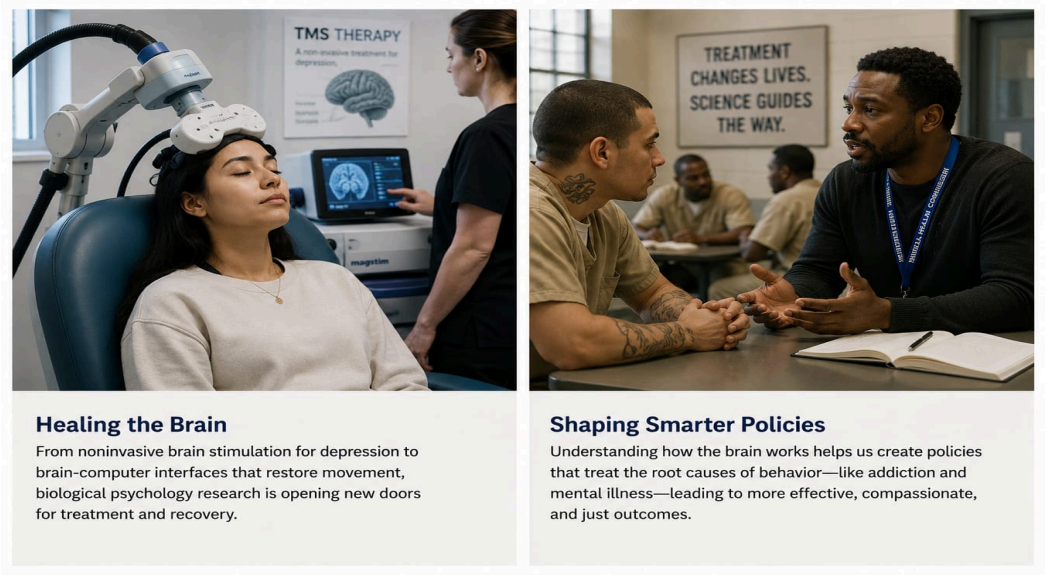
Studying the brain has also helped build **artificial intelligence (AI)**: tools like ChatGPT use networks of connected units loosely modeled on how neurons work together. And it goes both ways, because AI now helps scientists analyze brain scans and spot who may be at risk for diseases like Alzheimer’s.

Shaping Smarter Policies

Brain science is also changing how we think about addiction and mental health care. For example:

- Addiction isn’t just a choice. It involves changes in the brain. That’s why policies focused only on punishment often fail.
- Many people with mental illness don’t get the treatment they need, and some end up in jails and prisons instead. Treating the root causes in the brain works better than punishment alone.

The two-panel image below sums up two ways brain science helps: healing the brain and shaping smarter policies.



> **Image description:** A two-panel image. In “Healing the Brain,” a woman sits in a clinic chair with a TMS coil held against her head while a staff member checks a monitor. In “Shaping Smarter Policies,” a man who is incarcerated talks with a counselor at a table in a prison common room, under a sign that reads “Treatment changes lives. Science guides the way.” Short captions say that brain research opens doors for treatment and helps create policies that address root causes like addiction and mental illness.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

From a Peer

“I always got labeled as ‘angry’ or ‘trouble,’ but no one asked what my brain had been through. This class showed me I wasn’t broken. My brain was reacting to survival, and recovery is about healing the brain, not just willpower.”

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Unit 1.5: Research Ethics: Protecting Animals and People

Learning Objectives

By the end of this unit, you will be able to:

- Explain why psychologists sometimes study animals and summarize both sides of the debate.
- Describe the rules that protect animals in research.
- Describe how informed consent and review boards protect people who take part in research.

You'd think we'd learn about the human brain by just studying humans, right? And we do, a lot. But sometimes the only way to answer certain questions, or to test new treatments safely, is to study animals first. That might sound uncomfortable, and people have strong feelings about it. So here's what you need to know.

Most animal research in psychology today is done with rats, mice, or birds, not chimpanzees or dogs like you might see in movies. And researchers can't just do whatever they want. Animal studies must be approved by an ethics review board called an **Institutional Animal Care and Use Committee (IACUC)**. Its members include scientists, veterinarians, administrators, and community members, and it inspects animal facilities twice a year (Spielman et al., 2020b). The board checks that:

- The research is likely to benefit people or animals in a meaningful way
- There's no less harmful way to get the same results
- The animals are treated with care, and any pain or stress is kept as low as possible

Many researchers also follow the **3Rs**: *replace* animals with other methods when possible, *reduce* the number of animals used, and *refine* methods to keep pain and distress as low as possible (National Centre for the Replacement, Refinement and Reduction of Animals in Research [NC3Rs], n.d.).

The image below shows a lab rat, the kind of animal most often used in psychology research.



> **Image description:** A white lab rat runs on a blue exercise wheel inside a clear plastic cage lined with wood shavings. Behind the cage, out of focus, are a microscope and test tubes on a lab bench. The scene shows the kind of animal most often used in psychology research.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Some people believe it's never okay to use animals for research. Others believe the benefits, like finding new treatments for diseases or understanding how the brain works, make it worth doing as long as it's done humanely.

And to be fair, animal research has led to huge breakthroughs. It helped develop treatments for diseases like diabetes and

depression, and it's part of the ongoing search for Alzheimer's treatments. Some surgical techniques that save lives today were first practiced on animals. It has also helped us understand emotions like fear and stress on a deeper, biological level.

The truth? This is a complicated topic. There's no easy answer, and it's okay to have mixed feelings about it. What's important is that you understand both sides and think critically about how we balance ethics with scientific progress.

Protecting People in Research

Studies with people have strict rules too, and history shows why. In 1932, the U.S. Public Health Service began a study of syphilis with 600 Black men from Tuskegee, Alabama. The men who had syphilis were never told. By 1947, penicillin was known to treat the disease, but the men never received it. The study didn't end until 1972, when the press exposed it (Spielman et al., 2020b).

Public outrage led to the National Research Act of 1974 (Spielman et al., 2020b). A national commission then wrote the Belmont Report, which names three principles for research with people: *respect for persons* (people choose for themselves, and those less able to choose get extra protection), *beneficence* (do no harm, and maximize benefits while minimizing risks), and *justice* (share the benefits and burdens of research fairly) (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979).

Today, any institution that gets federal money for research with people must have an **institutional review board (IRB)**, a committee of administrators, scientists, and community members that reviews each study before it starts. Studies usually require **informed consent**: a written description of what will happen and what the risks are. Taking part is voluntary, you can stop at any time without penalty, and your information is kept confidential. For participants under 18, a parent or guardian signs (Spielman et al., 2020b).

Some groups get extra protection because they may not feel free to say no. For example, in prison research funded by the U.S. Department of Health and Human Services, the review board must include a prisoner or a prisoner representative, and people must be told ahead of time that taking part will have no effect on parole decisions (U.S. Department of Health and Human Services [HHS], n.d.).

From a Peer

"In a psych group, they talked about 'fight or flight,' and I didn't get where that came from. Reading about fear experiments with rats felt weird at first, but it made the science click and helped me understand my own reactions."

Check Your Understanding

1. Which animals are used most in psychology research today?
2. Name the three things an ethics review board checks before approving an animal study.
3. Name one breakthrough that animal research helped make possible.

The answers are in the unit you just read.

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Unit 1.6: Why Diversity Matters in Brain Science



> **Image description:** Five students and researchers of different genders and ethnic backgrounds gather around a colorful model of the brain in a lab. One wears a hijab and one wears a lab coat. Brain scans glow on a computer monitor, and a banner on the wall reads “Diversity, Equity, Inclusion.”

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Learning Objectives

By the end of this unit, you will be able to:

- Define WEIRD and explain why studying mostly WEIRD groups limits what science knows.
- Explain why diversity among researchers and among study participants makes brain science stronger.

As the image above shows, brain science is stronger when people from many backgrounds work together. When we talk about diversity in biological psychology, we mean two big things: who does the research, and who is being studied.

Let’s start with the researchers. For a long time, most brain researchers were white men from wealthy countries. That wasn’t because others weren’t capable. It was because of racism, sexism, money barriers, and lack of support. Today, more women and people from underrepresented groups are leading labs.

Why does this matter? Science thrives on different perspectives. When people from different backgrounds work together, they challenge each other, ask better questions, and find more creative solutions.

The same issue applies to who is being studied. By one estimate, about 96% of people in psychology studies come from “**WEIRD**” societies: Western, Educated, Industrialized, Rich, and Democratic. That’s a pretty small slice of humanity, and it means we may be missing important differences in how brains and behavior work across cultures, communities, and environments.

In Plain Words

Imagine deciding what food “everyone” likes by asking only the people on one block in one city. You’d get an answer, but it might not fit anybody else. That’s the problem with studying mostly WEIRD groups.

And it's not just about culture. Most mental health studies, such as research on genes linked to mental illness, have focused on people of European ancestry. But what about Black, Latino, Native American, and Asian populations? What about people who are poor, incarcerated, or living in rural areas? These groups often experience mental health challenges differently and may need different kinds of support or treatment, but the research isn't always there to guide that care.

Luckily, major organizations are now pushing for change. Funding agencies like the National Institute of Mental Health are encouraging more diverse research teams and study participants. It's not just about fairness. It's about making sure science helps everyone.

Close to Home

The Central Valley is home to farmworker families, rural towns, many Latino communities, and incarcerated people: exactly the groups research often leaves out. When Valley residents become researchers and study participants, science starts to reflect the people it's meant to help.

From a Peer

"I never saw myself or my family in the textbooks. Now I get why. If no one's studying people like us, how will they ever understand what we go through?"

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Unit 1.7: Module Wrap-Up

You made it through Module 1. Before you move on to the brain and nervous system, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Biological psychology is the study of how your body, especially your brain, connects to the way you think, feel, and act, and your brain's roughly 86 billion neurons make that connection possible (1.1).
- The field grew from the 1800s, got a major boost from Donald Hebb's 1949 book linking thoughts and memories to brain activity, and today includes branches such as psychopharmacology, neuropsychology, and behavioral genetics (1.2).
- Researchers look at the mind and brain from several perspectives, including the mind–body question, the evolutionary view, and the biopsychosocial view (1.2).
- The scientific method tests falsifiable hypotheses by changing an independent variable, measuring a dependent variable, and comparing an experimental group with a control group that may get a placebo (1.3).
- Replication and peer review help science build knowledge we can trust, while basic research asks why things happen and applied research asks how we can help (1.3).
- Brain research already helps people through treatments like TMS for depression, brain implants for Parkinson's disease, and brain–computer interfaces, and it is changing how policies treat addiction and mental illness (1.4).
- Animal studies, mostly with rats, mice, or birds, must be approved by an ethics review board, and studies with people require informed consent and approval from an institutional review board (1.5).
- By one estimate, about 96% of people in psychology studies come from WEIRD societies, so science needs more diverse researchers and participants to make sure it helps everyone (1.6).

Why This Module Matters

Every day, you hear claims about the brain: a supplement that "boosts memory," a headline about a new study, advice from family about stress or sleep. This module gave you the tools to ask good questions about those claims. Was it tested? Was there a control group? Did other scientists get the same result? Were people like you and your community even studied? Whether you're in class on campus or studying through Rising Scholars, these questions help you make better choices about your health and your family's health.

Module 1 ideas in everyday life

Idea	Where you met it	Where you might see it
Testable, falsifiable hypothesis	1.3	Checking whether a home remedy or workout tip really works, instead of just trusting it
Control group and placebo	1.3	A news story about a new medicine that was compared with a fake pill
Replication	1.3	A headline about one surprising study: wait to see if other scientists get the same result
Applied research	1.4	TMS for depression, or a brain–computer interface that helps someone with paralysis move a robotic arm
WEIRD samples	1.6	Asking whether a health study included farmworker families, rural towns, or people like you

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Think of a time your body reacted before you had a chance to think, like a racing heart before a test or a job interview, or jumping at a sudden loud noise. Looking back, what do you think your brain and body were doing in that moment?
2. Pick a piece of health advice you grew up hearing from family, friends, or your neighborhood. How could you use the steps of the scientific method to find out whether it really works?
3. Which brain-related issue matters most to you or the people around you: sleep, stress, addiction, brain injury, mental health, or something else? What would you want brain scientists to figure out about it?
4. Think about the people in your life and your community. Do you see them in the research you read about in this module? What would researchers need to understand about your community to study it fairly?

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Unit 1.8: References

About This Module

This module was adapted and rewritten by Michael Miguel from Chapter 1, “Introduction to Biological Psychology,” in *Biological Psychology* by Michael J. Hove and Steven A. Martinez (ROTEL Project, 2024), licensed CC BY-NC-SA 4.0. Changes: rewritten in a conversational style for Coalinga College campus and Rising Scholars students, with Central Valley examples, plain-language explainers, review questions, AI-generated images, and illustrative composite peer voices.

Web addresses are printed for reference only. You don’t need them to complete this module.

Parts of the original chapter were adapted from:

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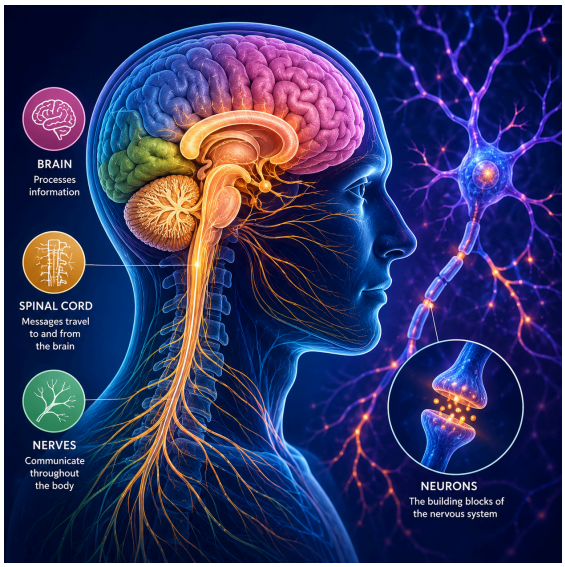
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MODULE 2: THE BRAIN AND NERVOUS SYSTEM



> **Image description:** A brightly colored artistic image on a dark blue background. A see-through head and neck, seen from the side, shows a rainbow-colored brain, an orange spinal cord running down the neck, and thin nerves branching out. Three round icons on the left are labeled “Brain: processes information,” “Spinal cord: messages travel to and from the brain,” and “Nerves: communicate throughout the body.” On the right, a glowing purple neuron and a close-up of a synapse releasing tiny bubbles are labeled “Neurons: the building blocks of the nervous system.” This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Your brain and nervous system let you think, feel, move, and make sense of the world. In this module, you’ll learn the main parts of the nervous system, how to find your way around the brain, and what the major brain areas do. You’ll also meet the **endocrine system**, the body’s slower, hormone-based way of sending messages.

Then you’ll see how scientists study the living brain, from famous injury cases to brain scans, and what happens when the brain is hurt by a stroke or a blow to the head.

There are a lot of new terms here. Focus on the big picture first. The vocabulary comes with practice, and every bolded term is in the Glossary.

Learning Objectives

By the end of this module, you will be able to:

- Use planes and directional terms to describe locations in the brain.
- Describe the main divisions of the nervous system and what each one does.
- Compare the sympathetic and parasympathetic nervous systems.
- Explain how the brain and spinal cord are protected and how a spinal reflex works.
- Identify the four lobes of the cortex and major structures below the cortex, and describe what each does.
- Describe how hormones from the endocrine system affect the body and behavior.
- Compare common methods for studying the brain, including what each can and cannot show.
- Describe the main types of stroke and traumatic brain injury, and recognize the warning signs of a stroke.

Unit 2.1: Introduction to the Nervous System

Unit 2.2: Finding Your Way Around the Brain
Unit 2.3: The Nervous System
Unit 2.4: The Peripheral Nervous System
Unit 2.5: The Central Nervous System
Unit 2.6: The Brain
Unit 2.7: The Endocrine System
Unit 2.10: Module Wrap-Up
Unit 2.8: How We Study the Brain
Unit 2.9: When the Brain Is Injured
Unit 2.11: References

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Unit 2.1: Introduction to the Nervous System

Learning Objectives

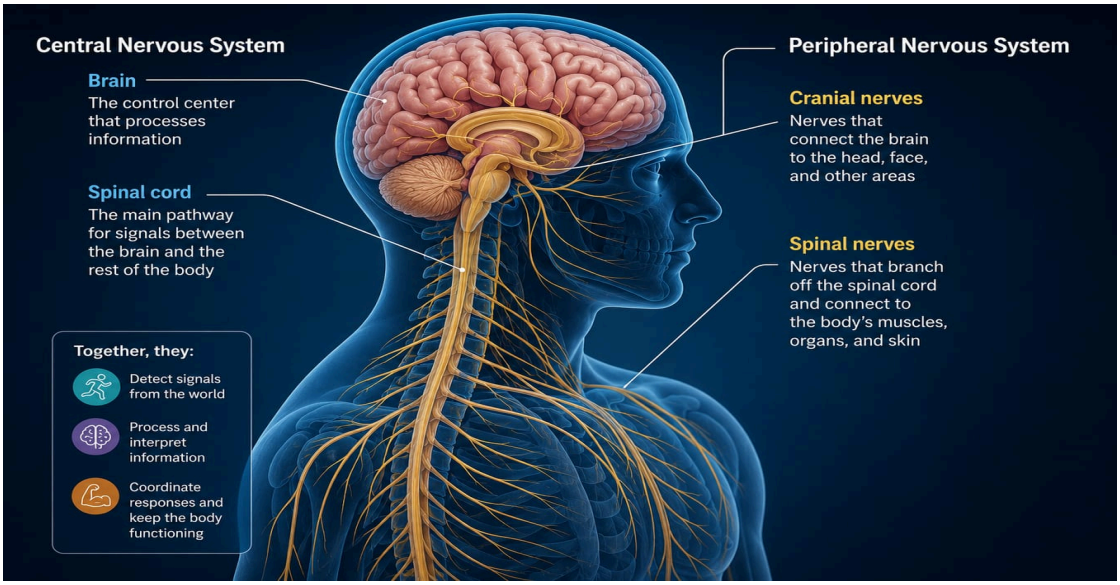
By the end of this unit, you will be able to:

- Describe what the nervous system does for thinking, feeling, and moving.
- Apply the module's study plan: big picture first, then key terms and brain parts.

In this module, you'll explore the physical structures that let you think, feel, move, and experience the world. They're the foundation for everything else in biological psychology.

This module can feel like a lot at first. There are new terms, detailed figures, and plenty of vocabulary. That's normal, and you're not expected to memorize everything on the first read. Here's a plan:

- First, get the big picture: how the parts work together.
- Then go back and learn the key terms and brain parts.
- Use the figures. They'll help things click.



> **Image description:** A see-through side view of a person's head and upper body on a dark blue background, showing the brain, the spinal cord, and yellow nerves. Labels on the left, under "Central Nervous System," name the brain ("the control center that processes information") and the spinal cord ("the main pathway for signals between the brain and the rest of the body"). Labels on the right, under "Peripheral Nervous System," name the cranial nerves ("nerves that connect the brain to the head, face, and other areas") and the spinal nerves ("nerves that branch off the spinal cord and connect to the body's muscles, organs, and skin"). A box says that together they detect signals from the world, process and interpret information, and coordinate responses to keep the body functioning.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

In Plain Words

Learning the brain is like learning your way around a new city. At first you know only a few main streets. With time and repetition, you learn the neighborhoods, the shortcuts, and how everything connects.

From a Peer

"When I first started this class, all the brain terms sounded like another language. But once I saw how doctors and therapists use these terms to talk about injuries and healing, it clicked. Now I feel like I'm learning the language of the brain, and that feels powerful."

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Unit 2.2: Finding Your Way Around the Brain

Learning Objectives

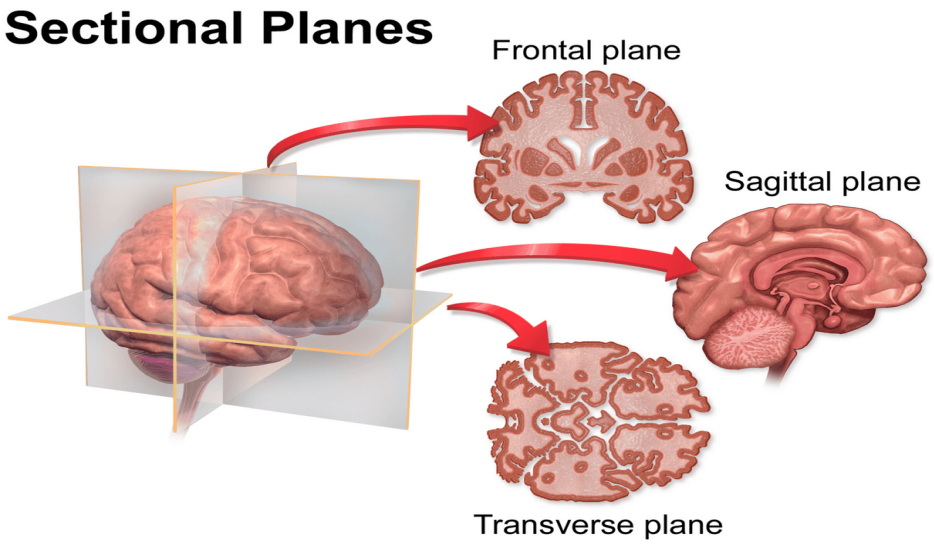
By the end of this unit, you will be able to:

- Identify the coronal, sagittal, and horizontal planes.
- Use directional terms such as anterior, posterior, dorsal, ventral, medial, and lateral to locate brain structures.
- Explain why “dorsal” means the top of the brain but the back of the spinal cord.

The brain is a 3D structure, but we usually study it in flat slices. To talk about it clearly, you need two tools: the three ways to slice it, and words for direction.

Three Ways to Slice the Brain

- **Coronal plane** (also called the frontal plane): divides the brain into front and back parts.
- **Sagittal plane**: divides the brain into left and right parts.
- **Horizontal plane** (also called the axial or transverse plane): divides the brain into upper and lower parts.



> **Image description:** A medical illustration titled “Sectional Planes.” On the left, a brain is crossed by three see-through panels. Red arrows point from the panels to the slices they make. The frontal (coronal) plane gives a front-facing slice through both halves of the brain. The sagittal plane gives a side view of the inside of one half, cut down the middle. The transverse (horizontal) plane gives a top-down slice.

Credit: “Sectional Planes of the Brain” (Blausen 0104) by BruceBlaus, Blausen.com staff (2014), “Medical gallery of Blausen Medical 2014,” WikiJournal of Medicine 1(2), doi:10.15347/wjm/2014.010, via Wikimedia Commons. CC BY 3.0.

Directional Terms

- **Anterior**: toward the front. **Posterior**: toward the back.
- **Superior**: toward the top. **Inferior**: toward the bottom.
- **Dorsal**: toward the top of the brain or the back of the body. **Ventral**: toward the bottom of the brain or the belly side of the body.

- **Medial**: toward the middle. **Lateral**: toward the sides.
- **Ipsilateral**: on the same side. **Contralateral**: on the opposite side.

Fun Fact

Dorsal means “back,” like a dolphin’s dorsal fin. Because we stand upright, our brain sits at an angle to our spinal cord. So dorsal means the top of the brain but the back of the spinal cord.

Like north, south, east, and west on a map, these terms will come up again and again, and they’ll start to feel natural with practice.

Check Your Understanding

1. Which plane divides the brain into left and right parts?
2. What does *contralateral* mean?
3. Is your forehead anterior or posterior to the back of your head?

The answers are in the unit you just read.

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Unit 2.3: The Nervous System

Learning Objectives

By the end of this unit, you will be able to:

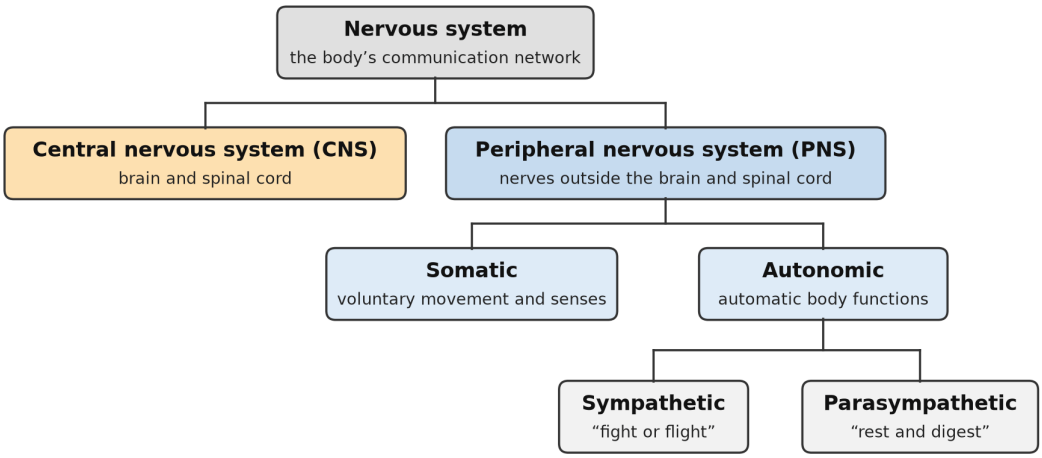
- Distinguish the central nervous system (CNS) from the peripheral nervous system (PNS).
- Describe the roles of the somatic and autonomic nervous systems.
- Compare the sympathetic (“fight or flight”) and parasympathetic (“rest and digest”) systems.

The nervous system has two main parts that work together as a fast communication network, keeping everything from breathing to problem-solving running smoothly.

The **central nervous system (CNS)** is the brain and spinal cord. It’s the main control hub: it takes in information, makes decisions, stores memories, and starts actions. The brain is where thoughts, emotions, and voluntary behavior begin. The **spinal cord** relays signals between the brain and body, and it can even handle some quick reflexes on its own.

The **peripheral nervous system (PNS)** is every nerve outside the brain and spinal cord. It carries information to and from the CNS. While the CNS makes the decisions, the PNS carries them out, like the nerves that move your fingers when you type or warn you when you touch something hot. It has two parts:

- The **somatic nervous system** handles voluntary movement, like walking or picking up a pencil, and carries information from your senses.
- The **autonomic nervous system** runs automatic body functions, like heartbeat, breathing, and digestion. Its **sympathetic nervous system** gets you ready to act (“fight or flight”), and its **parasympathetic nervous system** calms things down afterward (“rest and digest”).



> **Image description:** A tree diagram that reads from top to bottom. The nervous system (the body’s communication network) splits into the central nervous system (brain and spinal cord) and the peripheral nervous system (nerves outside the brain and spinal cord). The peripheral system splits into the somatic system (voluntary movement and senses) and the autonomic system (automatic body functions). The autonomic system splits into the sympathetic system (“fight or flight”) and the parasympathetic system (“rest and digest”).

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

In Plain Words

The CNS is headquarters. The PNS is the delivery network that brings news in from every part of the body and carries orders back out.

Why It Matters

This system helps explain everyday experiences: why we freeze when we're scared, why our heart races before a test, and why slow, deep breathing helps us calm down. Ongoing stress or past trauma can train the nervous system to stay on high alert. Awareness and practice can help shift that pattern over time.

Picture Maria on her first day back in college after years away. Her heart races, her palms sweat, and she feels like everyone is staring. That's her sympathetic system in full gear. Then a classmate smiles, and the professor greets her by name. Slowly, her parasympathetic system brings her body back into balance, and by the end of class she's breathing easier and thinking more clearly.

Check Your Understanding

1. What two structures make up the central nervous system?
2. Which part of the peripheral nervous system controls your heartbeat?
3. Which system is called "rest and digest"?

The answers are in the unit you just read.

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Unit 2.4: The Peripheral Nervous System

Learning Objectives

By the end of this unit, you will be able to:

- Compare the jobs of sensory neurons and motor neurons in the somatic nervous system.
- Explain how the two branches of the autonomic nervous system work like a gas pedal and a brake.
- Distinguish cranial nerves from spinal nerves.

The peripheral nervous system connects your brain and spinal cord to the rest of your body, including your arms, legs, organs, and skin. Without it, your brain couldn't sense what's going on or control what your body does.

The Somatic Nervous System

Soma means "body." The somatic system handles voluntary movement and your connection to the outside world. Its **sensory neurons** carry information to the central nervous system (CNS), like feeling heat or hearing a sound. Its **motor neurons** carry commands from the CNS to your muscles, like lifting your hand. You use it every time you scratch an itch, walk across a room, or turn your head when someone calls your name.

The Autonomic Nervous System

The autonomic system runs things behind the scenes: heartbeat, breathing, digestion, body temperature, and the release of some hormones. It has two branches that usually work in opposite directions, like a gas pedal and a brake. The sympathetic branch is the gas pedal: it gets your body ready to act fast when you're scared, stressed, or in danger. The parasympathetic branch is the brake: it helps you recover and restore. The table shows some of their effects.

Effects of the two branches of the autonomic nervous system

Body part	Sympathetic ("fight or flight")	Parasympathetic ("rest and digest")
Pupils	Widen (let in more light)	Narrow
Heart	Beats faster and harder	Slows down
Airways	Open wider	Narrow
Digestion	Slows down	Speeds up
Saliva	Less	More
Liver	Releases sugar for quick energy	Helps store energy

Close to Home

You're driving home on Highway 198 when a truck drifts into your lane. In a split second, your heart pounds, your hands grip the wheel, and your breathing speeds up. That's your sympathetic system. A few minutes after the danger passes, your heart slows and your shoulders drop as your parasympathetic system takes over. Working long hours in Valley summer heat puts the autonomic system to work too, as it speeds up your heart and makes you sweat to keep your body cool.

Cranial and Spinal Nerves

The peripheral nervous system (PNS) connects to the CNS through two sets of nerves. The 12 pairs of **cranial nerves** come

straight out of the brain and serve the head, face, and neck. Some carry only sensory information (like the olfactory nerve, for smell), some are mainly motor (like the oculomotor nerve, which moves your eyes), and some do both (like the glossopharyngeal nerve, for taste and swallowing).

The 31 pairs of **spinal nerves** branch off the spinal cord to the arms, legs, back, and chest. Each one carries both sensory fibers (body to spinal cord) and motor fibers (spinal cord to muscles). Nerves near your neck serve your shoulders and arms; nerves lower down serve your hips, legs, and feet.

From a Peer

"I never thought about how my body reacts to stress until I learned about the sympathetic nervous system. It made me understand why my heart races when I'm anxious, or why I freeze up in tough situations. Knowing it's my body trying to protect me helped me not feel so broken."

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Unit 2.5: The Central Nervous System

Learning Objectives

By the end of this unit, you will be able to:

- Describe how the meninges and cerebrospinal fluid protect the brain and spinal cord.
- Explain how the spinal cord carries afferent and efferent signals and controls reflexes.
- Explain why a higher spinal cord injury affects more of the body.

The central nervous system, your brain and spinal cord, is the main control center for everything you think, feel, and do. Because it's so important, it's well protected. Bone (the skull and the spine) surrounds it, and three layers of tissue called the **meninges** wrap it:

- **Dura mater** ("tough mother"): the thick, strong outer layer.
- **Arachnoid mater**: the middle layer, which looks a bit like a spider web.
- **Pia mater** ("tender mother"): a thin layer that hugs the brain and spinal cord closely.

Cerebrospinal fluid (CSF), a clear liquid, fills the space between the arachnoid and pia mater and the hollow spaces inside the brain (the ventricles). It cushions the brain and spinal cord against bumps and jolts.

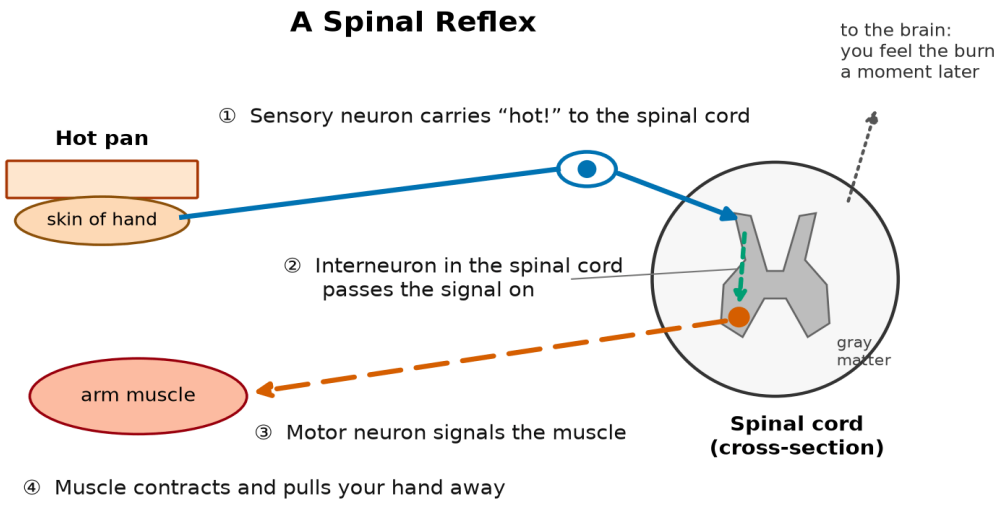
The Spinal Cord

The spinal cord runs from the base of your brain down your back. It's a two-way highway. **Afferent** signals travel toward the brain (like a feeling of touch), and **efferent** signals travel away from it (like a command to move a muscle).

In Plain Words

Afferent = arriving at the brain. *Efferent* = exiting the brain.

The spinal cord can also act on its own. When you touch a hot pan, your hand jerks away before your brain has time to register the pain. That fast, automatic response, a **reflex**, is handled right in the spinal cord.



> **Image description:** A diagram titled “A Spinal Reflex.” A hand touches a hot pan. (1) A sensory neuron (solid blue line) carries the signal from the skin to the spinal cord, shown as a round cross-section with butterfly-shaped gray matter in the middle. (2) Inside the gray matter, a short interneuron (green dashes) passes the signal on. (3) A motor neuron (orange dashes) carries a command back out to an arm muscle. (4) The muscle contracts and pulls the hand away. A dotted arrow from the spinal cord points up toward the brain: you feel the burn a moment later.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

The spinal cord also has built-in circuits for simple rhythms of movement, like walking. In studies with cats whose spinal cord was disconnected from the brain, the hind legs could still make stepping movements on a treadmill when the body was supported (Duysens & Van de Crommert, 1998).

When the Spinal Cord Is Injured

A spinal cord injury can cause paralysis, the loss of movement and feeling in parts of the body. The higher the injury, the more of the body it affects. Jason, a 21-year-old student-athlete, took a hard hit during a football game and didn’t get up. He had a C5 spinal cord injury, high in the neck. He lost most movement and feeling below his shoulders and needed help breathing at first. In rehab, he regained some use of his arms and learned to use adaptive technology to live more independently. Today, he speaks to students about perseverance and brain science.

Scientists are testing new treatments, like stem cells to help repair damaged nerves, but healing the spinal cord is still one of neuroscience’s hardest challenges.

Key Takeaways

- The brain and spinal cord are protected by bone, the three meninges, and cerebrospinal fluid.
- Afferent signals travel toward the brain; efferent signals travel away from it.
- Reflexes are fast, automatic responses handled by the spinal cord.
- The higher a spinal cord injury, the more of the body it affects.

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Unit 2.6: The Brain

Learning Objectives

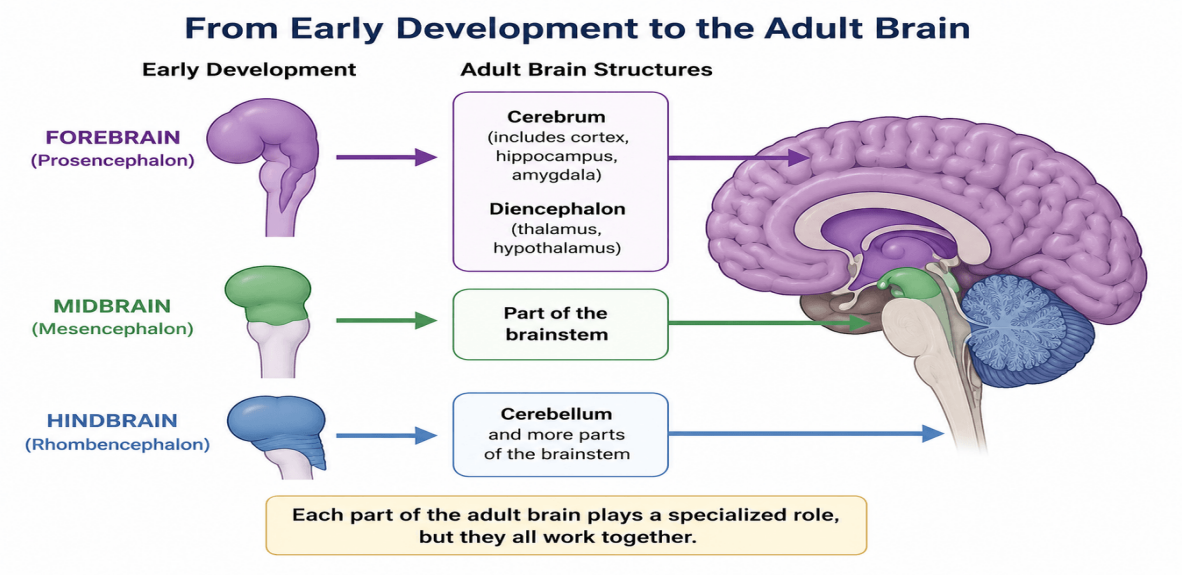
By the end of this unit, you will be able to:

- Identify the four lobes of the cerebral cortex and describe what each one does.
- Describe the roles of structures below the cortex, such as the hippocampus, amygdala, thalamus, and hypothalamus.
- Describe what the cerebellum and brainstem do.

Your brain has about 86 billion neurons (Herculano-Houzel, 2009), each connecting with many others. Together they let you think, move, feel, remember, and be you.

How the Brain Is Organized

Early in development, the brain forms three main regions. The **forebrain** becomes the cerebrum (including the cortex, hippocampus, and amygdala) plus the thalamus and hypothalamus. The **midbrain** becomes part of the brainstem. The **hindbrain** becomes the cerebellum and the rest of the brainstem. The infographic below shows which adult brain parts grow from each of these three early regions.



> **Image description:** An infographic titled “From Early Development to the Adult Brain.” On the left are simple shapes of the three regions of the early brain. Arrows link each one to a box and then to a color-coded inside view of the adult brain. The forebrain (prosencephalon, purple) becomes the cerebrum (including the cortex, hippocampus, and amygdala) and the diencephalon (thalamus and hypothalamus). The midbrain (mesencephalon, green) becomes part of the brainstem. The hindbrain (rhombencephalon, blue) becomes the cerebellum and more parts of the brainstem. A note at the bottom says each part of the adult brain plays a specialized role, but they all work together.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

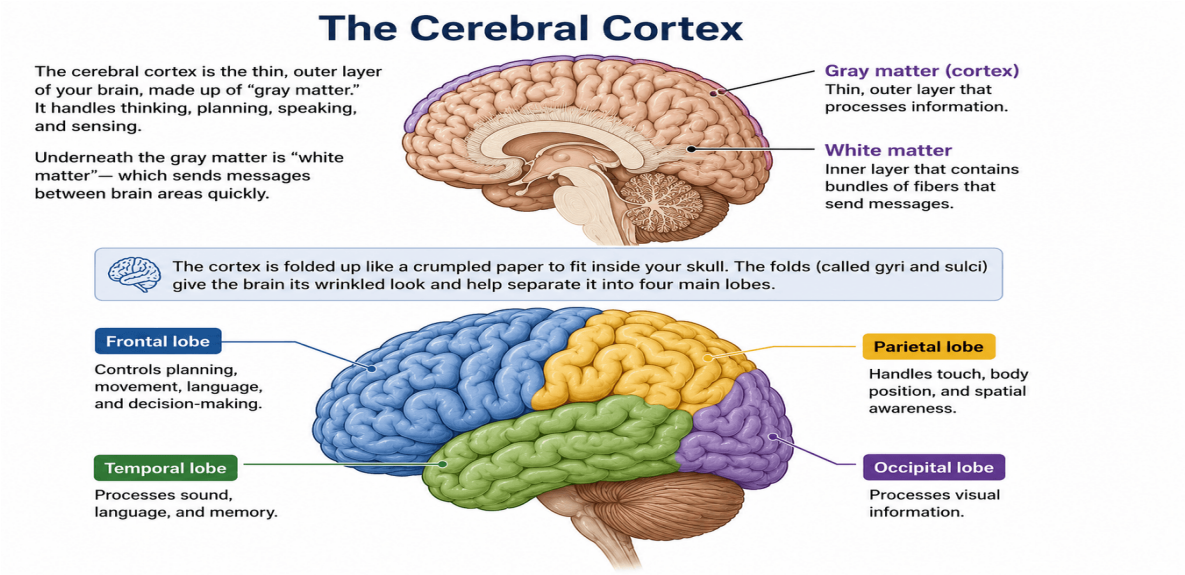
The Cerebral Cortex

The **cerebral cortex** is the brain’s thin, wrinkled outer layer. It’s made of **gray matter**, mostly neuron cell bodies, and it handles thinking, planning, language, and sensing. Beneath it lies **white matter**, bundles of myelinated axons that carry messages

between brain areas. The folds of the cortex fit a large surface into the skull and help divide each half (hemisphere) into four lobes:

- **Frontal lobe**: planning, decision-making, movement, and speech production.
- **Parietal lobe**: touch, body position, and awareness of space.
- **Temporal lobe**: hearing, language understanding, and memory.
- **Occipital lobe**: vision.

The infographic below shows the gray and white matter and the four lobes.



> **Image description:** An infographic titled "The Cerebral Cortex." At the top, an inside view of the brain marks the thin outer layer of gray matter (the cortex), which processes information, and the white matter beneath it, bundles of fibers that send messages. A note explains that the cortex is folded like crumpled paper and that the folds (gyri and sulci) help separate it into four lobes. Below, a side view of the brain, facing left, colors the lobes: the frontal lobe (blue, front) controls planning, movement, language, and decision-making; the parietal lobe (yellow, top toward the back) handles touch, body position, and spatial awareness; the temporal lobe (green, lower side) processes sound, language, and memory; and the occipital lobe (purple, back) processes visual information.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

In Plain Words

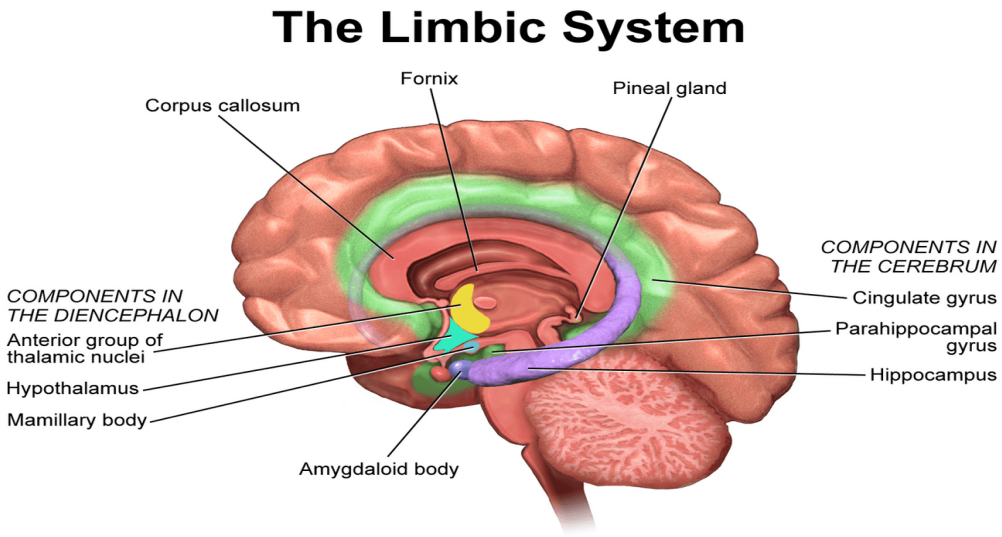
Think of the lobes as departments in a big company. Each has its own specialty, but the work only gets done when they share information.

A thick band of white matter, the **corpus callosum**, connects the left and right hemispheres. The **motor cortex**, at the back of the frontal lobe, controls voluntary movement, and the **somatosensory cortex**, just behind it in the parietal lobe, processes body sensations. For most people, two language areas sit in the left hemisphere: **Broca's area** (frontal lobe) helps produce speech, and **Wernicke's area** (temporal lobe) helps understand it. You'll see both again in the Language module.

Below the Cortex

- **Hippocampus**: forming new memories and finding your way.
- **Amygdala**: emotions, especially fear.
- **Basal ganglia**: movement and learning habits and routines.
- **Thalamus**: a relay hub that passes sensory information to the cortex.
- **Hypothalamus**: hunger, thirst, body temperature, and hormones.

The hippocampus, amygdala, and nearby structures form the **limbic system**, a network for emotion, motivation, and memory. The illustration below shows these limbic structures inside the brain.



> **Image description:** A medical illustration titled “The Limbic System,” showing the inside of one half of the brain. Colored structures curve around the middle of the brain. Labels on the right (parts in the cerebrum) mark the cingulate gyrus, parahippocampal gyrus, and hippocampus. Labels on the left (parts in the diencephalon) mark the anterior group of thalamic nuclei, the hypothalamus, and the mammillary body. Labels across the top and bottom mark the corpus callosum, fornix, pineal gland, and amygdaloid body (amygdala).

Credit: “Limbic System” (Blausen 0614) by BruceBlaus, Blausen.com staff (2014), “Medical gallery of Blausen Medical 2014,” WikiJournal of Medicine 1(2), doi:10.15347/wjm/2014.010, via Wikimedia Commons. CC BY 3.0.

Other Key Structures

The **cerebellum**, at the back of the brain, helps you move smoothly, keep your balance, and learn physical skills. The **brainstem** connects the brain to the spinal cord and controls vital functions. It has three parts: the midbrain (eye movements and quick responses to sights and sounds), the **pons** (a bridge that relays signals and helps with sleep and breathing), and the **medulla** (heartbeat, breathing, and blood pressure). Tucked inside a deep fold, the **insula** helps you sense your body’s inner state and is involved in emotion, pain, and taste.

Check Your Understanding

1. Which lobe processes vision?
2. What does the corpus callosum connect?
3. Which structure helps you form new memories?

The answers are in the unit you just read.

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Unit 2.7: The Endocrine System

Learning Objectives

By the end of this unit, you will be able to:

- Define hormones and name the major endocrine glands.
- Describe what key glands do, such as the pituitary and adrenal glands.
- Compare how hormones and nerves send messages.

The nervous system isn't the body's only messenger. The endocrine system is a set of glands that release **hormones**, chemical messengers that travel through the bloodstream. Hormone signals are slower than nerve signals, but they last longer and influence energy, mood, sleep, stress, growth, and development.

Major Glands

- **Hypothalamus**: links the brain to the endocrine system, mostly by directing the pituitary.
- **Pituitary gland**: the "master gland," which signals other glands and helps control growth, water balance, and reproduction.
- **Pineal gland**: makes melatonin, which helps set your sleep-wake cycle.
- **Thyroid gland**: sets the pace of metabolism.
- **Adrenal glands**: make cortisol (a stress hormone) and adrenaline (for fight or flight).
- **Pancreas**: makes insulin and glucagon to control blood sugar.
- **Gonads** (ovaries and testes): make sex hormones like estrogen and testosterone.

The diagram below shows where the major endocrine glands are in the body.

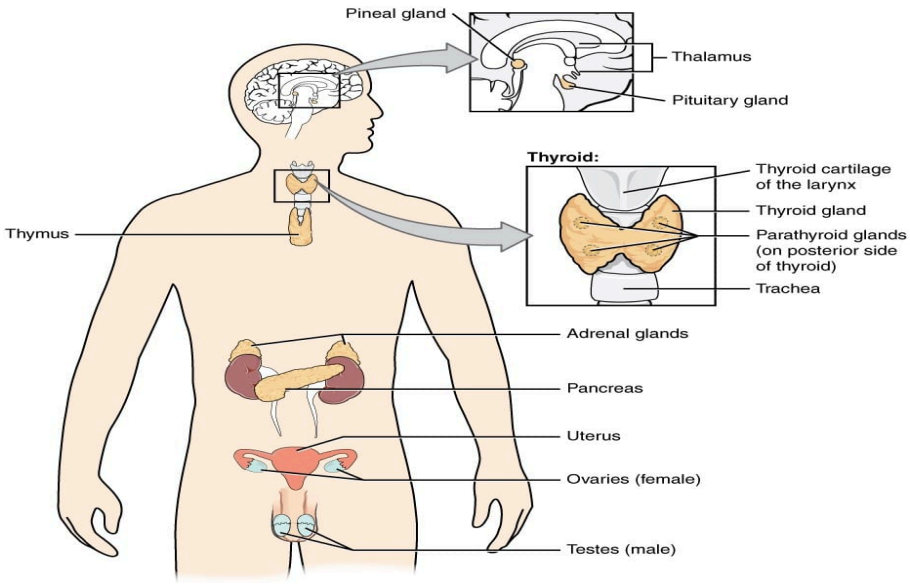


Image description: An outline of a human body with the major endocrine glands labeled. A close-up of the brain shows the pineal gland, the thalamus, and the pituitary gland (the hypothalamus, just above the pituitary, is not labeled). A close-up of the neck shows the thyroid gland with four small parathyroid glands on its back side. The thymus sits in the chest. The adrenal glands sit on top of the kidneys, near the pancreas. Lower in the body are the uterus and ovaries (female) and the testes (male).

Credit: "The Endocrine System" (Figure 17.2 / 1801) from Anatomy & Physiology by OpenStax College, via Wikimedia Commons. CC BY 3.0. Access for free at https://openstax.org/books/anatomy-and-physiology-2e

Hormones and Behavior

Hormones help explain why you feel jumpy after a scare (adrenaline) and why ongoing stress can wear you out (cortisol). The rise in sex hormones during puberty is one of many influences on teen moods. Hormones don't control behavior, but they shape the physical and emotional state we respond from.

Close to Home

During harvest, a parent works long shifts at a packing house, then studies late for a college class. When a supervisor criticizes their work, a wave of anxiety and exhaustion hits. Their adrenal glands are releasing cortisol, which helps the body handle short-term stress but can take a toll when stress goes on for weeks. Coping tools like slow breathing, exercise, sleep, and support from others can help calm the stress response, even when life doesn't get easier.

Key Takeaways

- Endocrine glands release hormones into the blood; they act more slowly than nerves, but their effects last longer.
- The hypothalamus links the brain to the endocrine system through the pituitary gland.
- Cortisol and adrenaline from the adrenal glands help the body respond to stress.
- Hormones influence behavior but don't control it.

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Unit 2.10: Module Wrap-Up

You made it through Module 2. Before you move on to neurons, the cells that do the brain's talking, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Learning the brain is a lot like learning your way around a new city, so it helps to get the big picture first and then go back for the key terms and brain parts (2.1).
- Scientists describe the brain using three planes (coronal, sagittal, and horizontal) and pairs of direction words like anterior and posterior, and dorsal means the top of the brain but the back of the spinal cord (2.2).
- The central nervous system, your brain and spinal cord, makes the decisions, while the peripheral nervous system carries messages between it and the rest of your body (2.3).
- In the peripheral nervous system, the somatic system handles your senses and voluntary movement, and the autonomic system's sympathetic ("fight or flight") and parasympathetic ("rest and digest") branches work like a gas pedal and a brake (2.3, 2.4).
- Bone, three layers of meninges, and cerebrospinal fluid protect the brain and spinal cord, and the spinal cord carries signals to and from the brain and handles fast reflexes on its own (2.5).
- Each half of the cerebral cortex has four lobes (frontal, parietal, temporal, and occipital), and deeper structures like the hippocampus, amygdala, thalamus, and hypothalamus, along with the cerebellum and brainstem, each have their own jobs (2.6).
- Endocrine glands release hormones into the blood, which act more slowly than nerve signals but last longer, and hormones shape your mood and energy without controlling your behavior (2.7).
- Injury cases like Phineas Gage's and Broca's patient "Tan" showed that specific brain areas handle specific jobs, and today researchers record, picture, or change activity in the living brain with tools that differ in what they can show and in whether they are invasive (2.8).
- Most strokes happen when a clot or narrowed artery blocks blood flow to the brain, and B.E. F.A.S.T. helps you spot the warning signs and call 911 right away (2.9).
- Most traumatic brain injuries are concussions, a second blow before the brain heals can cause much worse damage, and rehabilitation and neuroplasticity help many people regain skills (2.9).

Why This Module Matters

Your nervous system is at work in every part of your day. Your heart pounds when a truck drifts into your lane on Highway 198, your body sweats to keep you cool during long hours in the Valley summer heat, and stress hormones rise when a long shift meets a late night of studying.

Knowing which part of your body is doing what can make those reactions feel less scary and easier to manage. It can also help you act fast when it counts, like spotting the signs of a stroke in a family member or knowing that a teammate with a possible concussion should sit out.

Module 2 ideas in everyday life

Idea	Where you met it	Where you might see it
Sympathetic and parasympathetic systems	2.3, 2.4	Your heart racing on your first day back in class, then slowing as you settle in
Spinal reflex	2.5	Jerking your hand away from a hot pan before you even feel the pain
Cortisol	2.7	Feeling worn out after weeks of stress, like long shifts during harvest season
B.E. F.A.S.T.	2.9	Noticing a relative's face drooping or their speech slurring, and calling 911 right away

Idea	Where you met it	Where you might see it
Concussion	2.9	A hard hit in a Friday night football game: “when in doubt, sit it out”

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Think of a recent moment when your “fight or flight” system kicked in. What did you notice in your body, and what helped you calm down afterward?
2. Which part of the brain from this module do you think you use most in your daily life or work? What makes you say that?
3. Have you or someone close to you had a concussion, a stroke, or another brain injury? Looking back, what do you understand now that you didn’t before?
4. This module had a lot of new terms. Which study habits helped you most, and what would you try differently in the next module?

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Unit 2.8: How We Study the Brain

Learning Objectives

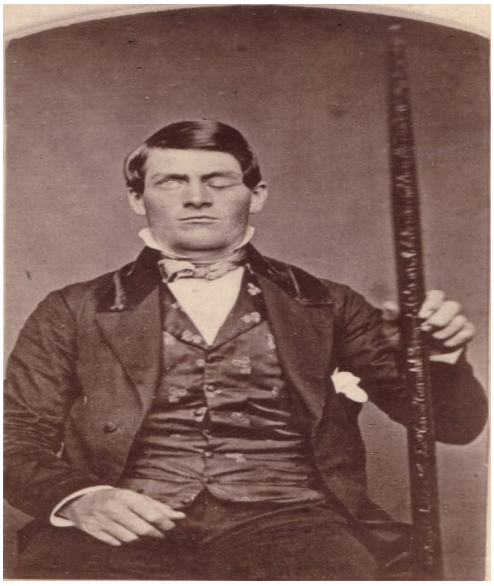
By the end of this unit, you will be able to:

- Explain what cases like Phineas Gage's and Broca's patient "Tan" showed about localization of function.
- Compare methods that record, picture, or change brain activity, including their temporal and spatial resolution.
- Classify brain research methods as invasive or non-invasive.

How do we know what each part of the brain does? Some of the first clues came from people whose brains were injured. Today, researchers also use tools that record or change activity in the living brain.

Clues from Brain Injuries

In 1848, Phineas Gage was a railroad construction foreman in Vermont. While he packed explosive powder into a rock with a long iron rod, a spark set it off. The rod shot up through his left cheek, behind his left eye, and out the top of his head. Amazingly, he survived, and he could talk and walk soon after.



> **Image description:** A sepia photographic portrait from the 1850s. Phineas Gage sits facing the camera in a dark jacket, patterned vest, and bow tie. His left eye, injured in the accident, is closed. In his left hand he holds the tamping iron that injured him, a long metal rod that reaches above his head.

Credit: Cabinet-card portrait of Phineas P. Gage (1823–1860), photographer unknown, from the Gage family of Texas photo collection, via Wikimedia Commons. Public Domain.

Gage lost part of his frontal lobe (Damasio et al., 1994). His memory and intelligence seemed unchanged, but his doctor reported that his personality changed: once reliable, he became impulsive, rude, and unable to stick to plans (Harlow, 1868). The case suggested that the frontal lobe helps control impulses and social behavior. Gage's story also has a hopeful ending that's often left out. In later years, he worked for about seven years as a stagecoach driver in Chile, a job that took planning and people skills. This suggests he regained much of what he had lost (Macmillan & Lena, 2010).

In the 1860s, the French doctor Paul Broca studied a patient nicknamed "Tan," who understood speech but could say little besides the word "tan." After the patient died, Broca found damage in the left frontal lobe, the area now called Broca's area. A few years

later, Carl Wernicke described patients who spoke fluently but made little sense and had trouble understanding speech. They had damage in the left temporal lobe. Cases like these support **localization of function**, the idea that specific brain areas handle specific jobs.

Injury cases have limits, though. Every injury is different, and damage rarely stays in one area. Scientists can't damage human brains on purpose, so they sometimes make small, precise **lesions** (areas of damage) in the brains of lab animals and study what changes.

Recording the Brain's Activity

Electroencephalography (EEG) uses small sensors on the scalp, often held in a cap, to record the brain's electrical activity. EEG has excellent **temporal resolution**: it shows *when* something happens, down to the millisecond. But its **spatial resolution**, how precisely it shows *where* activity happens, is poor, because the signals blur as they pass through the skull and scalp. Doctors use EEG to diagnose seizures and sleep disorders.

Magnetoencephalography (MEG) records the tiny magnetic fields that brain activity produces. It's just as fast as EEG and better at pinpointing location, but it's expensive and needs a specially shielded room.

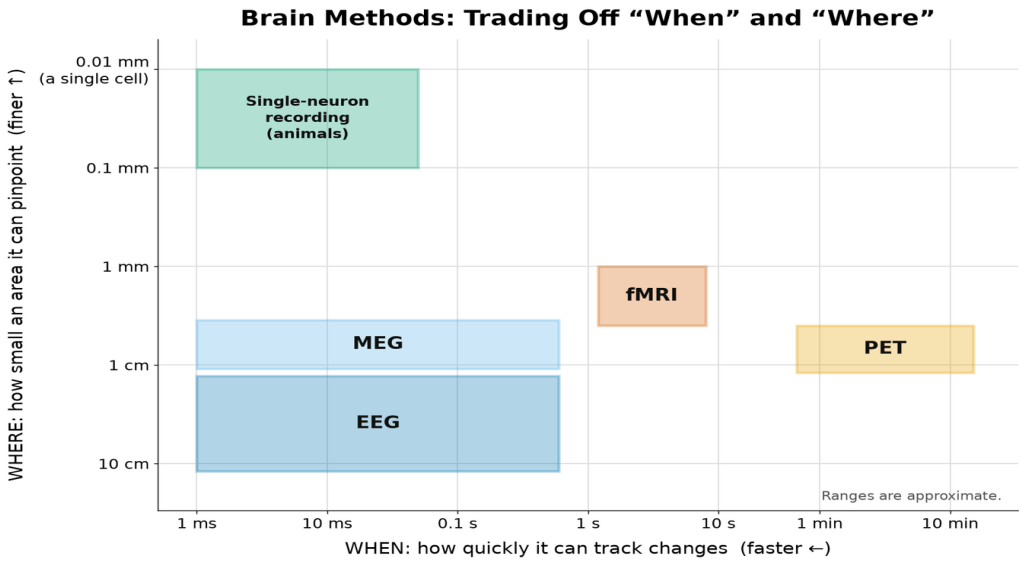
Taking Pictures of the Brain

Some scans show the brain's structure. A **computerized tomography (CT)** scan uses X-rays. It's fast, so emergency rooms use it to check for bleeding after a stroke or head injury. **Magnetic resonance imaging (MRI)** uses a strong magnet and radio waves to make detailed, harmless pictures of the brain. A type of MRI called **diffusion tensor imaging (DTI)** maps the white matter pathways that connect brain areas.

Other scans show the brain at work. In **positron emission tomography (PET)**, a small amount of a radioactive tracer is injected into the blood, and the scanner detects where it gathers in active brain areas. **Functional MRI (fMRI)** uses an MRI scanner to track activity. When a brain area works harder, fresh oxygen-rich blood flows to it over the next few seconds. fMRI detects this change, called the BOLD (blood-oxygen-level-dependent) signal, and researchers infer which areas were active. fMRI can pinpoint areas a few millimeters across, but each snapshot averages about 2–3 seconds of activity.

In Plain Words

fMRI tracks blood, not neurons. It's like judging which part of town is busy by watching traffic: more cars head to where the action is, but they arrive a little late.



> **Image description:** A chart titled “Brain Methods: Trading Off ‘When’ and ‘Where.’” The horizontal axis shows how quickly a method can track changes, from 1 millisecond to 10 minutes. The vertical axis shows how small an area it can pinpoint, from a single cell (top) to 10 centimeters (bottom). EEG covers milliseconds but only a few centimeters of precision. MEG is just as fast and a little more precise. fMRI takes a few seconds but pinpoints areas a few millimeters across. PET takes about a minute or more and pinpoints areas several millimeters across. Single-neuron recording in animals is both fast and precise down to single cells. Ranges are approximate.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

fMRI images are striking, but they’re correlational. They show which areas are active during a task, not whether those areas cause the behavior.

Changing Brain Activity

To test cause and effect, researchers change brain activity and watch what happens. **Transcranial magnetic stimulation (TMS)** uses a magnetic coil held over the scalp to briefly boost or quiet the brain area underneath. TMS is also used to treat some people with depression (Perera et al., 2016). **Transcranial direct current stimulation (tDCS)** sends a weak electrical current through electrodes on the scalp. In animals, **optogenetics** uses light to switch specific, genetically targeted neurons on or off.

Every method has strengths and weaknesses. Researchers trust a finding most when different methods point to the same answer, called **converging evidence**.

The table below sums up what each brain research method does and whether it is invasive.

Brain research methods at a glance

Method	What it does	Invasive?
Lesions	Changes the brain (damages a small area)	Invasive; animals only (in research)
Implanted electrodes	Records single neurons	Invasive; mainly animals
Optogenetics	Changes activity with light	Invasive; animals
EEG and MEG	Records activity	Non-invasive
CT	Pictures structure	Non-invasive, but uses X-rays
MRI and DTI	Pictures structure	Non-invasive
PET	Pictures activity	Needs an injected radioactive tracer
fMRI	Pictures activity (the BOLD signal)	Non-invasive
TMS and tDCS	Changes activity	Non-invasive

Note. Based on Grose-Fifer & Olman (2025) and Hove & Martinez (2024).

Check Your Understanding

1. What did the Phineas Gage case suggest about the frontal lobe?
2. Which is better at showing *when* brain activity happens: EEG or fMRI?
3. What change in the brain does fMRI actually detect?
4. Name one method that changes brain activity instead of just recording it.

The answers are in the unit you just read.

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Unit 2.9: When the Brain Is Injured

Learning Objectives

By the end of this unit, you will be able to:

- Distinguish ischemic and hemorrhagic strokes.
- Identify the B.E. F.A.S.T. warning signs of a stroke.
- Describe how traumatic brain injury happens and how neuroplasticity supports recovery.

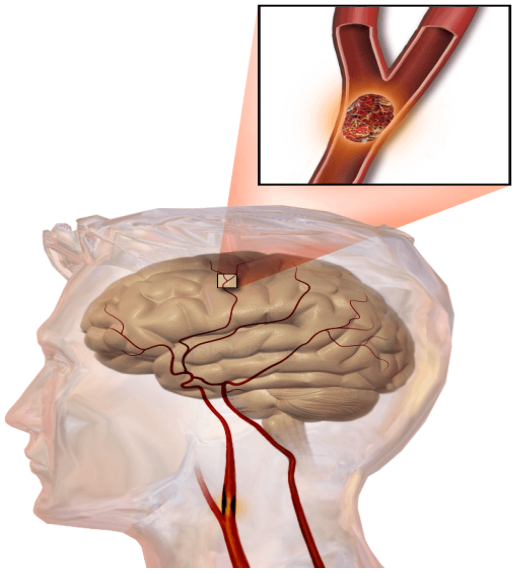
Your brain is well protected, but it can still be hurt. Two of the most common causes of brain injury are strokes and blows to the head. Knowing the warning signs can help you act fast, for yourself or someone else.

Stroke

A **stroke** happens when blood flow to part of the brain is interrupted. Without oxygen and nutrients, neurons stop working within seconds and begin to die within minutes. Stroke is a leading cause of serious long-term disability in adults (Centers for Disease Control and Prevention [CDC], 2024).

There are two main types. Most strokes are **ischemic strokes**, in which a blood clot or a narrowed artery blocks blood flow. A **hemorrhagic stroke** happens when a blood vessel in the brain leaks or bursts, and the blood damages nearby brain cells (National Institute of Neurological Disorders and Stroke [NINDS], 2023a).

The illustration below shows a blood clot blocking an artery in the brain, the cause of an ischemic stroke.



> **Image description:** A see-through side view of a person's head, showing the brain and the red arteries that supply it, running up from the neck. A small square on the top of the brain is enlarged in a box above: an artery that branches in two, with a dark red blood clot blocking it. This blockage is what happens in an ischemic stroke.

Credit: "Stroke" (Blausen 0836) by Blausen Medical Communications, Blausen.com staff (2014), "Medical gallery of Blausen Medical 2014," WikiJournal of Medicine 1(2), doi:10.15347/wjm/2014.010, via Wikimedia Commons. CC BY 3.0. Modified: transparent background changed to white.

The effects depend on where the damage is. A stroke on one side of the brain often weakens the opposite (contralateral) side of

the body. A stroke near Broca's or Wernicke's area can affect language.

Act B.E. F.A.S.T.

With a stroke, every minute counts. Use the letters B.E. F.A.S.T. to spot the signs (CDC, 2026):

- **B**alance loss: the person suddenly feels off-balance or dizzy.
- **E**ye (vision) changes: the person suddenly has trouble seeing normally.
- **F**ace drooping: one side of the face droops or feels numb.
- **A**rm weakness: one arm is weak or drifts down when both are raised.
- **S**peech difficulty: speech is slurred or strange.
- **T**ime to call 911: call right away, and note when the signs started.

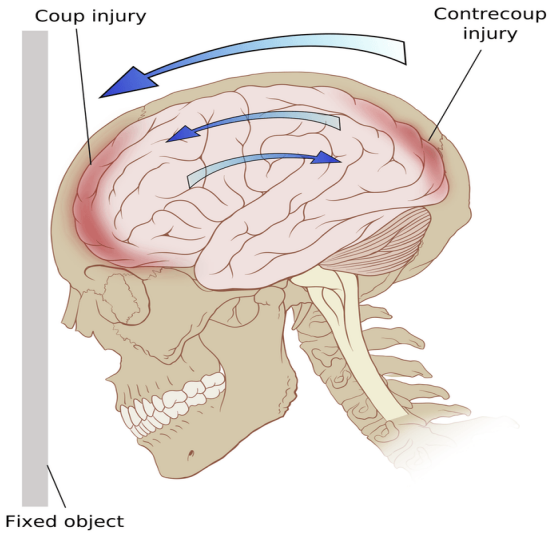
Hospitals can give clot-dissolving medicine for many ischemic strokes, but only in the first few hours. Many strokes can be prevented (CDC, n.d.). High blood pressure is the most important risk factor that people can control. Not smoking, staying active, and managing diabetes also lower the risk.

Traumatic Brain Injury

A **traumatic brain injury (TBI)** is brain damage caused by an outside force: a bump, blow, or jolt to the head, or an object that pierces the skull. Falls and vehicle crashes are common causes. Most TBIs are mild, and the most common mild TBI is a **concussion**. Signs can include headache, confusion, dizziness, memory problems, and feeling foggy. Most people recover within weeks, but some have symptoms for months or longer (NINDS, 2023b).

When the head stops suddenly, the brain can hit the inside of the skull and then bounce back against the opposite side. This can bruise the brain in two places: under the impact (a **coup** injury) and on the opposite side (a **contrecoup** injury). Twisting forces can also stretch and tear axons throughout the brain.

The diagram below shows how a coup and a contrecoup injury happen.



> **Image description:** A side view of a skull with the brain inside, moving toward a gray post labeled "fixed object." A large arrow shows the head's motion toward the post. Inside, two smaller arrows show the brain sliding forward and then bouncing back. Red shading marks two injured areas: a "coup injury" at the front, where the brain hits the skull, and a "contrecoup injury" at the back, on the opposite side.

Credit: "Contrecoup" by Patrick J. Lynch, medical illustrator, via Wikimedia Commons. CC BY 2.5. Modified: rendered as PNG on a white background.

A second blow before the brain has healed can cause much worse damage, so anyone with a possible concussion should stop playing or working and get checked. Repeated head impacts over many years, as in some contact sports, are linked to **chronic traumatic encephalopathy (CTE)**, a brain disease that can affect memory, mood, and behavior. For now, CTE can be confirmed only by examining the brain after death.

Close to Home

On Friday nights across the Valley, high school football players take hard hits. In one national survey, about 15 percent of high school students reported a sports or recreation concussion in the past year (DePadilla et al., 2018). Head injuries happen at work, too, from falls off ladders and equipment on farms and oil fields. Helmets, seat belts, safe ladder habits, and "when in doubt, sit it out" rules all help protect the brain.

Recovery and Support

After an injury, the brain can partly rewire itself, a process called **neuroplasticity**. Rehabilitation, such as physical, occupational, and speech therapy, helps people relearn skills. Recovery can take months or years, and support from family and community matters.

Past brain injuries are far more common among people in jails and prisons than in the general population (Shiroma et al., 2010). An injury that was never treated can make it harder to focus, control impulses, or keep track of appointments, and others may mistake this for not caring. Screening for past head injuries and offering the right support can help people succeed in school, at work, and at home.

From a Peer

"I had a couple of concussions playing ball and never thought much about it. Learning about TBI helped me understand why I sometimes lose my train of thought. Now I use a planner and ask for notes, and it really helps."

Key Takeaways

- A stroke interrupts blood flow to part of the brain. Most are ischemic (a blockage); some are hemorrhagic (bleeding).
- Remember B.E. F.A.S.T.: Balance, Eyes, Face, Arms, Speech, Time to call 911.
- Most traumatic brain injuries are concussions. A second blow before healing can cause serious damage.
- Rehabilitation and neuroplasticity help many people regain skills after a brain injury.

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Unit 2.11: References

About This Module

This module was adapted and rewritten by Michael Miguel from Chapters 2, 4, and 11 of *Biological Psychology* by Michael J. Hove and Steven A. Martinez (ROTEL Project, 2024), licensed CC BY-NC-SA 4.0. Changes: rewritten in plain, conversational language for Coalinga College campus and Rising Scholars students, with Central Valley examples, plain-language explainers, review questions, two new units (2.8 and 2.9), and new or openly licensed images. Terms are defined in the book Glossary.

The ROTEL chapters were adapted in part from:

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MODULE 3: NEURONS



> **Image description:** A brightly colored artistic image of a neuron against a dark blue background filled with other faint neurons. The large purple cell body has a round nucleus and many branching dendrites. Glowing orange streaks of energy run through the cell and out along the axon, which is wrapped in segments of myelin. A magnified circle in the lower right shows the end of the axon, where tiny glowing bubbles release chemical messengers across a small gap onto receptors on the next cell. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Every thought, feeling, and movement you have starts with tiny cells called **neurons** passing messages to each other. In this module, you'll look inside a single neuron, meet the other cells that support it, and follow a message as it travels through one neuron and jumps to the next.

There are a lot of new terms here. Don't worry about memorizing them all at once. Focus on the big picture: neurons use electricity to send a message *within* a cell and chemicals to send it *between* cells.

Learning Objectives

By the end of this module, you will be able to:

- Describe the neuron doctrine and how Cajal's work supported it.
- Identify the main parts of a neuron and what each part does.
- Compare sensory neurons, motor neurons, and interneurons, and name the main types of glial cells.
- Explain resting potential, threshold, and the action potential.
- Describe how neurotransmitters carry a message across the synapse.
- Give examples of common neurotransmitters and what they do.

Unit 3.1: Introduction to Neurons

Unit 3.2: The Structure of the Neuron

Unit 3.3: Types of Cells in the Brain

Unit 3.4: Communication Within and Between Neurons

Unit 3.5: Synaptic Transmission

Unit 3.6: Module Wrap-Up
Unit 3.7: References

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Unit 3.1: Introduction to Neurons

Learning Objectives

By the end of this unit, you will be able to:

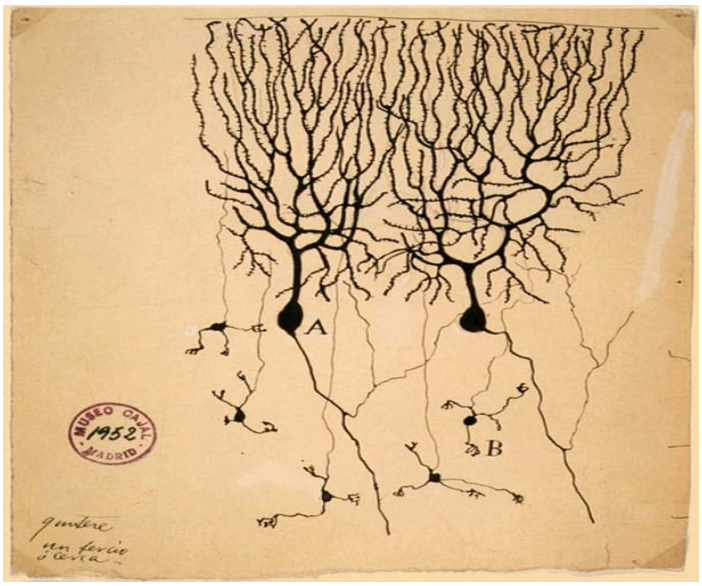
- Describe how the Golgi stain helped Santiago Ramón y Cajal see whole neurons.
- Explain the neuron doctrine.

Imagine trying to understand a sentence without knowing what any of the words mean. Understanding the brain works the same way: first you need to know its basic units, the neurons.

Here's something surprising: a neuron from a rat and a neuron from a human have the same basic structure. So how do billions of these simple-looking cells let us laugh, remember, argue, write poetry, or fall in love? That's what this module is about.

A Peek into the Past

Over a century ago, the Spanish scientist Santiago Ramón y Cajal used a special dye called the **Golgi stain** to look at brain tissue. Most stains of the time colored only the cell body. The Golgi stain filled in a few whole neurons, branches and all, so Cajal could draw them in detail. The drawing below is one of Cajal's, from 1899.



> **Image description:** A hand-drawn sketch in black ink on yellowed paper. Two large neurons, marked A, each have a dark cell body with a thick trunk of dendrites branching upward like the crown of a tree, and a thin axon running down. Several much smaller neurons, marked B, sit below them. Because the Golgi stain filled in only a few whole cells, Cajal could see that each neuron is a separate cell.

Credit: "Purkinje cells (A) and granule cells (B) from pigeon cerebellum" by Santiago Ramón y Cajal, 1899, Instituto Cajal, Madrid, via Wikimedia Commons. Public Domain.

Before Cajal, most scientists thought the nervous system was one continuous net, like a giant spiderweb. Cajal showed that neurons are separate cells that communicate across tiny gaps. This idea is called the **neuron doctrine**, and it's still the foundation of brain science today.

Fun Fact

In 1906, Cajal shared the Nobel Prize with Camillo Golgi, the scientist who invented the stain. Golgi still believed in the “one big net” idea, so Cajal had used Golgi’s own tool to prove him wrong.

From a Peer

“The first week, all the new words made me want to quit. Then I started making flash cards on the bus and saying them out loud. By the time we got to synapses, it finally clicked. You don’t have to get it all the first time.”

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Unit 3.2: The Structure of the Neuron

Learning Objectives

By the end of this unit, you will be able to:

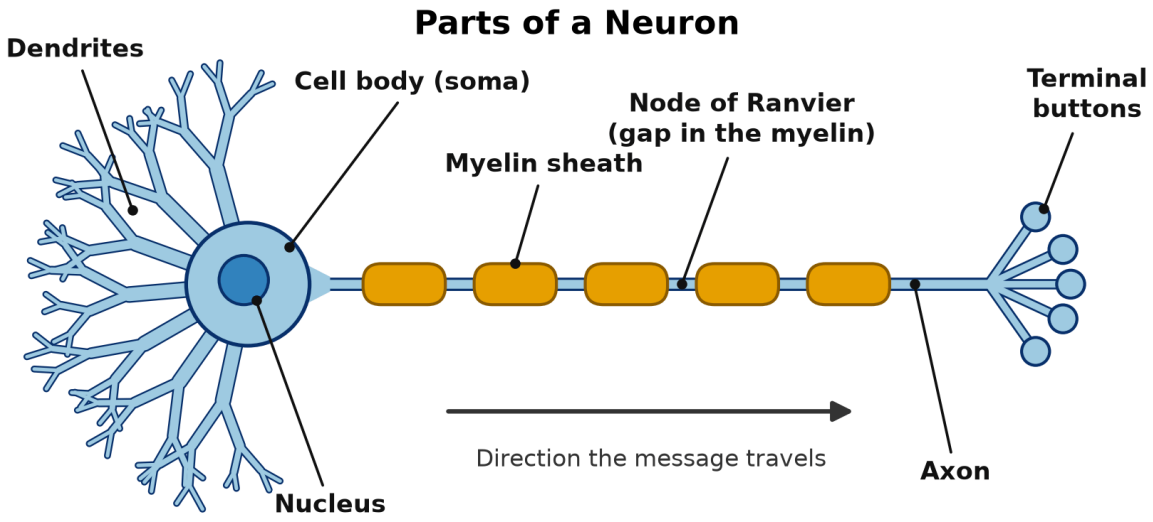
- Identify the dendrites, cell body, axon, myelin sheath, and terminal buttons and describe what each does.
- Describe the parts of a synapse.
- Explain how neurotransmitters carry a message from one neuron to the next.

Your brain has about 86 billion neurons. That's a huge number, but each one has a fairly simple layout.

Three Main Parts

- **Dendrites** are branch-like extensions that receive messages from other neurons.
- The **cell body**, or **soma**, holds the nucleus (where the cell's DNA, or deoxyribonucleic acid, is) and keeps the cell alive.
- The **axon** is a long extension that carries the message away from the cell body, toward other neurons, muscles, or glands.

Many axons are wrapped in a **myelin sheath**, a fatty coating that works like insulation on a wire and helps messages travel faster. The diagram below labels each of these parts.



> **Image description:** A single neuron drawn from left to right. On the left, many branching dendrites lead into a round cell body (soma) with a nucleus inside. A long axon runs to the right, wrapped in five orange segments of myelin sheath with small bare gaps between them, called nodes of Ranvier. At the far right, the axon splits into short branches that end in round terminal buttons. An arrow below points left to right, showing the direction the message travels.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Making Connections: Synapses

At the end of the axon are small knobs called **terminal buttons**. Each one forms a **synapse**, a connection point with another neuron. The neuron sending the message is the **presynaptic neuron**, and the neuron receiving it is the **postsynaptic neuron**.

They don't actually touch. A tiny space called the **synaptic cleft** sits between them, only about 20 to 40 nanometers wide. That's tens of thousands of times thinner than a dime.

Inside the terminal buttons are **synaptic vesicles**, little packets filled with chemical messengers called **neurotransmitters**. When a signal reaches the end of the axon, the vesicles release their neurotransmitters into the cleft. The chemicals cross the gap and attach to **receptors** on the next neuron, passing the message along.

In Plain Words

Sending a message through a neuron is like sending a text. The signal travels through the wires (the axon), then jumps through the air (the synapse), and the other person's phone picks it up (the receptors).

Check Your Understanding

1. Which part of a neuron receives messages from other neurons?
2. What does the myelin sheath do?
3. What is the name of the tiny gap between two neurons?
4. What do synaptic vesicles hold?

The answers are in the unit you just read.

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Unit 3.3: Types of Cells in the Brain

Learning Objectives

By the end of this unit, you will be able to:

- Compare sensory neurons, motor neurons, and interneurons.
- Classify neurons by shape as unipolar, bipolar, or multipolar.
- Describe the jobs of the main types of glial cells.

Not all neurons do the same job. Some bring information in, some send commands out, and some connect the two.

Three Main Types of Neurons

- **Sensory neurons** carry information from your senses, like heat, sound, or pain, toward the brain and spinal cord.
- **Motor neurons** carry commands from the brain and spinal cord to your muscles so you can move.
- **Interneurons** sit inside the brain and spinal cord and connect sensory and motor neurons. They do most of the processing.

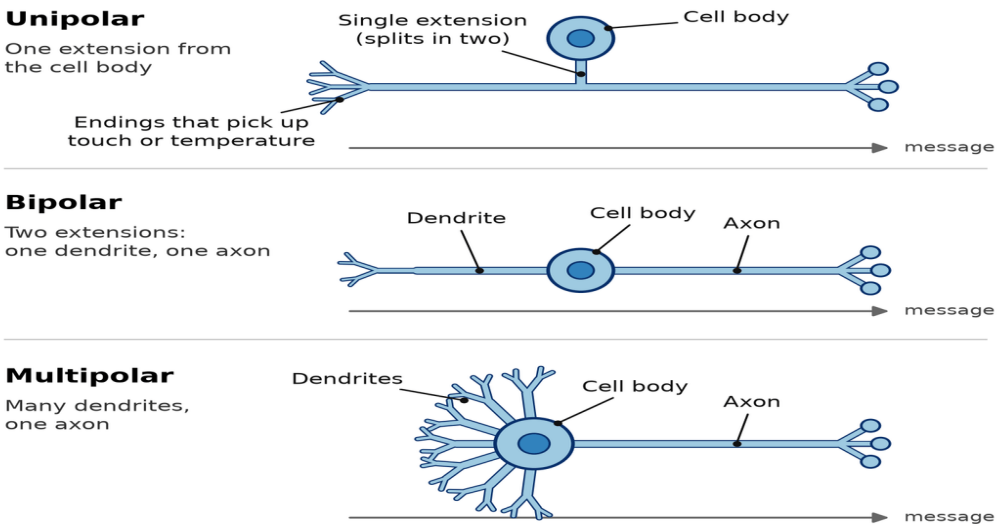
Close to Home

Grab a steering wheel that's been baking in a Coalinga parking lot on a July afternoon. Sensory neurons in your hand report "hot!", interneurons in your spinal cord pass the alarm along, and motor neurons pull your hand back. By the time you think "ouch," your hand has already moved.

Neurons by Shape

- **Unipolar neurons** have a single extension. Many sensory neurons, such as those that carry touch and temperature from your skin, have this shape.
- **Bipolar neurons** have one dendrite and one axon. They're found in places like the eye, where they help pass along signals about light.
- **Multipolar neurons** have one axon and many dendrites. They're the most common type in the brain.

An easy way to remember: uni means one, bi means two, and multi means many. The diagram below compares the three shapes.



> **Image description:** Three neurons stacked in rows, each with an arrow showing the message moving left to right. Unipolar: the cell body sits off to the side on a single short extension that splits in two; one end has endings that pick up touch or temperature, and the other ends in terminal buttons. Bipolar: the cell body is in the middle, with one dendrite on the left and one axon on the right. Multipolar: many branching dendrites surround the cell body, and one long axon extends to the right.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Glial Cells: The Support Crew

Neurons do the talking, but **glial cells** keep them working. Glial cells don't send messages the way neurons do. Key types include:

- **Oligodendrocytes** make myelin for axons in the brain and spinal cord.
- **Schwann cells** make myelin for nerves in the rest of the body.
- **Microglia** clean up dead cells and debris, like the brain's cleanup crew.
- **Astrocytes** are star-shaped cells that bring nutrients from blood vessels and keep the chemical balance around neurons steady.

Check Your Understanding

1. Which type of neuron carries commands to your muscles?
2. Where are interneurons found?
3. Which is the most common type of neuron in the brain?
4. Which glial cells make myelin in the brain and spinal cord?

The answers are in the unit you just read.

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Unit 3.4: Communication Within and Between Neurons

Learning Objectives

By the end of this unit, you will be able to:

- Describe the resting potential and the role of the sodium-potassium pump.
- Explain how EPSPs and IPSPs add up to reach threshold and trigger an all-or-none action potential.
- Explain how myelin and saltatory conduction speed up signals.

Neurons "talk" with a mix of electricity and chemicals. Inside a neuron, the message is electrical. Between neurons, it's chemical. This unit covers the electrical part.

Resting Potential

Even when a neuron isn't sending a message, it's charged and ready, a bit like a battery. Inside, it's slightly negative compared to outside, about −70 millivolts. This is the **resting potential**.

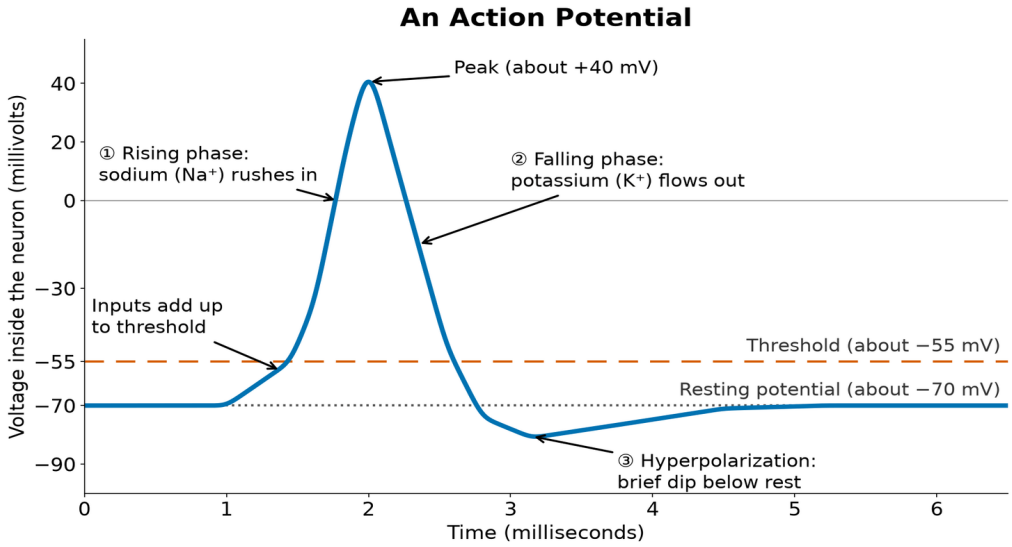
The charge comes from **ions**, tiny particles with an electrical charge. At rest, there's more sodium outside the cell and more potassium inside, along with negatively charged particles that stay inside. The **sodium-potassium pump** keeps this balance by moving sodium out and potassium in.

The Action Potential

A neuron receives many small inputs from other neurons. **Excitatory postsynaptic potentials (EPSPs)** push it closer to firing, and **inhibitory postsynaptic potentials (IPSPs)** push it further away. The neuron adds them all up, which is called **summation**.

If the total reaches the **threshold**, about −55 millivolts, the neuron fires an **action potential**:

- Sodium rushes into the cell, and the inside becomes positive, up to about +40 millivolts.
- Potassium then flows out, bringing the charge back down. It briefly dips below the resting level before settling back.
- The whole spike lasts only a millisecond or two.



> **Image description:** A line graph titled “An Action Potential,” with voltage inside the neuron (millivolts) on the vertical axis and time (0 to 6 milliseconds) on the horizontal axis. The line starts flat at the resting potential, about −70 mV. Starting at 1 millisecond, inputs push it up to a dashed threshold line at about −55 mV. Then it shoots up as sodium rushes in, peaking at about +40 mV at about 2 milliseconds. It falls quickly as potassium flows out, dips briefly below rest to about −80 mV (hyperpolarization), and returns to −70 mV by about 5 milliseconds.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

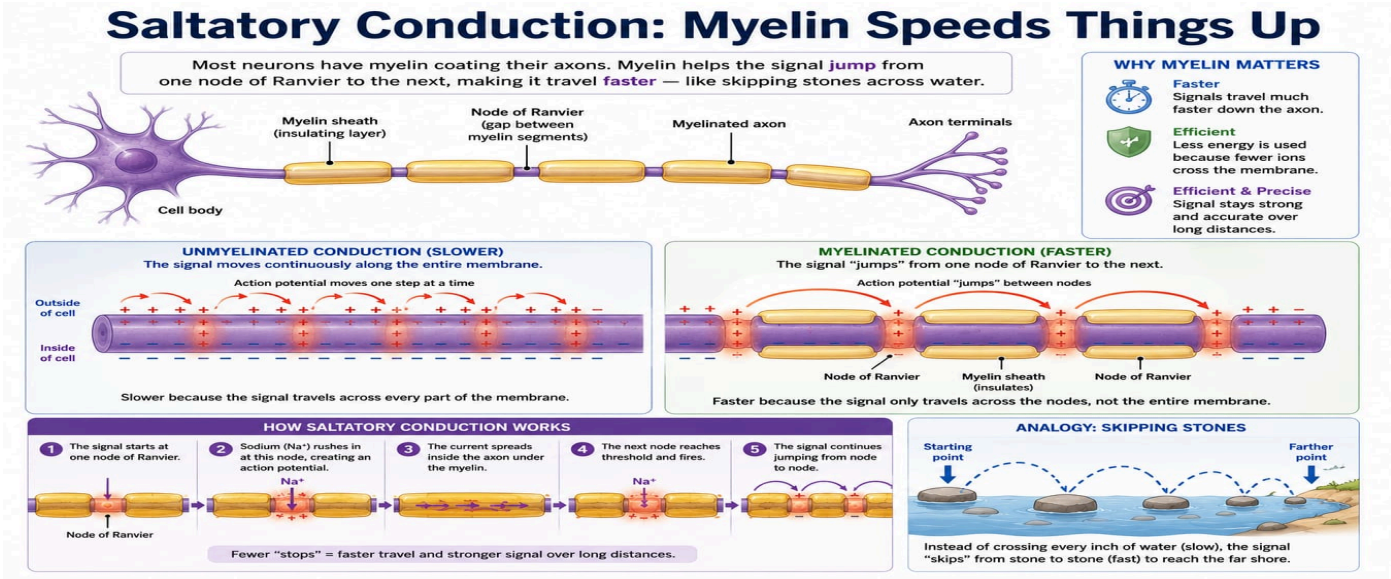
An action potential is **all-or-none**: the neuron either fires completely or not at all. A stronger signal doesn't make a bigger spike. It makes the neuron fire more often.

In Plain Words

Think of a toilet flush. Pushing the handle a little does nothing. Push past a certain point and it flushes all the way, the same every time. Then it needs a moment to refill before it can flush again.

Myelin Speeds Things Up

On a myelinated axon, the signal jumps from one gap in the myelin to the next. These gaps are called **nodes of Ranvier**, and the jumping is called **saltatory conduction**, from the Latin word for “to leap.” It's much faster than creeping along a bare axon, like a stone skipping across water.



> **Image description:** An infographic titled “Saltatory Conduction: Myelin Speeds Things Up.” At the top, a neuron is labeled with its cell body, myelin sheath (insulating layer), nodes of Ranvier (gaps between myelin segments), myelinated axon, and axon terminals. A middle panel compares unmyelinated conduction (slower: the signal moves step by step along the whole membrane) with myelinated conduction (faster: the signal “jumps” from one node of Ranvier to the next). A bottom strip shows the steps: sodium rushes in at a node, current spreads inside the axon under the myelin, and the next node reaches threshold and fires. A final panel compares this to a stone skipping across water. A side panel titled “Why Myelin Matters” lists three benefits: Faster (signals travel much faster down the axon), Efficient (less energy is used because fewer ions cross the membrane), and Efficient & Precise (the signal stays strong and accurate over long distances).

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Close to Home

Mia is a nursing student at Coalinga College. During a hospital clinical shift, she steps on a dropped thumbtack. Before she can think, she lifts her foot. Sensory neurons sent an action potential to her spinal cord, interneurons passed it on, and motor neurons told her leg muscles to pull back. A moment later, signals reaching her brain let her feel the pain and decide to grab a bandage.

Key Takeaways

- A resting neuron sits at about −70 millivolts.
- If inputs add up to threshold (about −55 millivolts), it fires an all-or-none action potential that peaks around +40 millivolts.
- Myelin lets the signal jump from node to node, so it travels faster.

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Unit 3.5: Synaptic Transmission

Learning Objectives

By the end of this unit, you will be able to:

- Describe the steps of synaptic transmission.
- Identify common neurotransmitters, such as glutamate, GABA, dopamine, serotonin, and acetylcholine, and their general roles.
- Explain how reuptake clears the synapse and how some medications affect it.

When an action potential reaches the end of the axon, it hits a gap. Neurons don't touch, so how does the message get across? The answer is neurotransmitters.

How Synaptic Transmission Works

1. The action potential reaches the terminal buttons.
2. Vesicles release neurotransmitters into the synaptic cleft.
3. The neurotransmitters drift across the cleft and attach to receptors on the next neuron.
4. Depending on the neurotransmitter and receptor, this makes the next neuron more likely to fire (excitatory) or less likely to fire (inhibitory).

The infographic below shows each step.

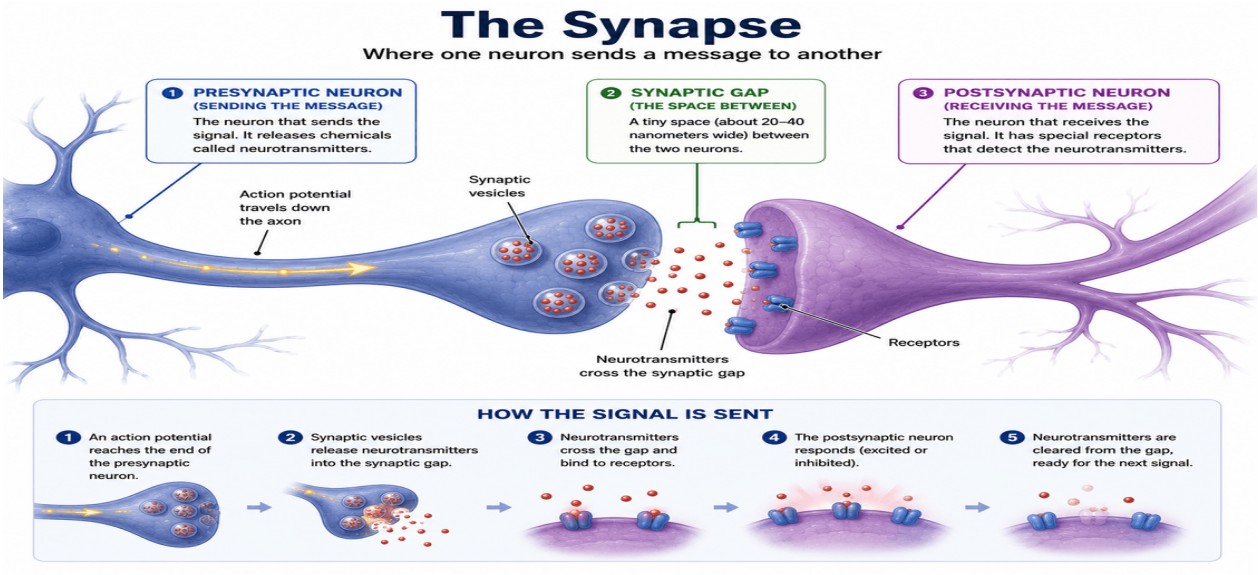


Image description: An infographic titled "The Synapse: Where one neuron sends a message to another." On the left, an action potential travels down the axon of the presynaptic (sending) neuron to a rounded ending filled with synaptic vesicles holding neurotransmitters. The neurotransmitters spill into the synaptic gap (the synaptic cleft, "about 20–40 nanometers wide") and attach to receptors on the postsynaptic (receiving) neuron on the right. A strip along the bottom shows five steps: (1) an action potential reaches the end of the presynaptic neuron; (2) vesicles release neurotransmitters into the gap; (3) neurotransmitters cross the gap and bind to receptors; (4) the postsynaptic neuron responds (excited or inhibited); (5) neurotransmitters are cleared from the gap, ready for the next signal.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Common Neurotransmitters

- **Glutamate** is the brain's main excitatory neurotransmitter and is important for learning and memory.
- **GABA** (gamma-aminobutyric acid) is the main inhibitory neurotransmitter. It calms neural activity.
- **Dopamine** plays roles in reward, motivation, and movement.
- **Serotonin** is involved in mood, sleep, and appetite.
- **Acetylcholine** tells muscles to move and helps with memory.

Clearing the Gap

After the message is passed, neurotransmitters have to leave the cleft so the synapse is ready for the next one. They're either taken back into the sending neuron (**reuptake**), broken down by enzymes, or cleared away by nearby glial cells.

Problems in these chemical systems are linked to conditions like depression, anxiety, schizophrenia, and Parkinson's disease. Many medications work by changing how neurotransmitters are released, received, or cleared. You'll learn more in the Psychopharmacology module.

From a Peer

"My doctor told me my medication helps serotonin stay in the synapse longer. I just nodded. Now I actually get what that means: it slows down reuptake. Understanding it made me feel more in control of my own treatment."

Check Your Understanding

1. What do vesicles release into the synaptic cleft?
2. Which neurotransmitter is the brain's main excitatory messenger, and which is the main inhibitory one?
3. Name the three ways neurotransmitters are cleared from the synapse.
4. Which neurotransmitter tells your muscles to move?

The answers are in the unit you just read.

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Unit 3.6: Module Wrap-Up

You made it through Module 3. Before you move on to genes, development, and how your brain keeps changing, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Using the Golgi stain, Santiago Ramón y Cajal showed that neurons are separate cells that communicate across tiny gaps, an idea called the neuron doctrine that is still the foundation of brain science (3.1).
- A neuron's dendrites receive messages, its cell body keeps the cell alive, and its axon carries the message away, often sped along by a fatty myelin sheath (3.2).
- At a synapse, the sending neuron releases neurotransmitters into a tiny gap called the synaptic cleft, and those chemicals attach to receptors on the next neuron (3.2).
- Sensory neurons bring information in, motor neurons send commands to your muscles, and interneurons in the brain and spinal cord connect the two and do most of the processing (3.3).
- Glial cells are the brain's support crew: they make myelin, clean up debris, and keep neurons fed and their chemical surroundings steady (3.3).
- A resting neuron holds a small negative charge of about −70 millivolts, and when its inputs add up to threshold, it fires an all-or-none action potential (3.4).
- On a myelinated axon, the action potential jumps from one node of Ranvier to the next, so the signal travels much faster (3.4).
- Neurotransmitters such as glutamate, GABA, dopamine, serotonin, and acetylcholine make the next neuron more or less likely to fire, and they are cleared away by reuptake, by enzymes, or by glial cells (3.5).
- Many medications work by changing how neurotransmitters are released, received, or cleared, such as medicines that slow the reuptake of serotonin (3.5).

Why This Module Matters

Every time you feel heat, move a muscle, or remember a name, billions of neurons are passing messages: electrical inside each cell and chemical between cells. That might sound far from daily life, but it explains a lot, like why you pull your hand off a steering wheel baking in a Coalinga parking lot before you even think "ouch." It also helps you make sense of health information. When a doctor says a medicine helps serotonin stay in the synapse longer, you now know what that means, and you can ask better questions about your own treatment.

Module 3 ideas in everyday life

Idea	Where you met it	Where you might see it
Reflex pathway	3.3, 3.4	Pulling your hand off a hot steering wheel, or lifting your foot off a dropped thumbtack, before you feel the pain
All-or-none action potential	3.4	A toilet flush: push past a certain point and it goes all the way, the same every time
Neurotransmitters	3.5	Hearing that a medicine or a condition involves serotonin or dopamine
Reuptake	3.5	A doctor explaining that a medicine helps serotonin stay in the synapse longer

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Think of a time you reacted to something before you had time to think, like touching something hot. Can you trace the path

the message took, from sensory neurons to motor neurons?
2. Neurons do the talking, but glial cells keep them working behind the scenes. Who is the “support crew” in your own life that helps you keep going?
3. If you or someone close to you takes a medicine that affects the brain, what questions would you now feel more confident asking a doctor or pharmacist?
4. Which part of this module was hardest to understand at first? What helped it click, or what could you try next time?

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Unit 3.7: References

About This Module

This module was adapted and rewritten by Michael Miguel from Chapter 3, “Neurons,” in *Biological Psychology* by Michael J. Hove and Steven A. Martinez (ROTEL Project, 2024), licensed CC BY-NC-SA 4.0. Changes: rewritten in plain, conversational language for Coalinga College campus and Rising Scholars students, with Central Valley examples, plain-language explainers, review questions, and new or redrawn images. Terms are defined in the book Glossary.

The ROTEL chapter was adapted from:

Furtak, S. (n.d.). Neurons. In R. Biswas-Diener & E. Diener (Eds.), *Noba textbook series: Psychology*. DEF Publishers. https://noba.to/s678why4. Licensed CC BY-NC-SA 4.0.

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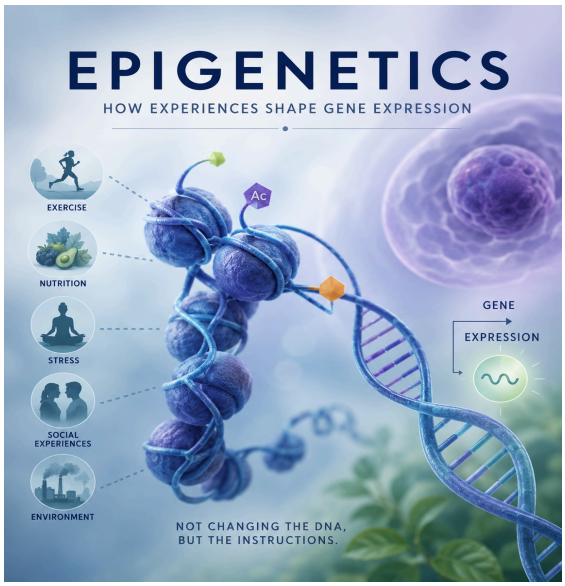
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MODULE 4: GENES, DEVELOPMENT, AND PLASTICITY



> **Image description:** An artistic poster titled “Epigenetics: How Experiences Shape Gene Expression.” A strand of DNA winds around round, ball-shaped proteins (histones), and small colored tags, one marked “Ac,” stick out from them. Icons down the left side are labeled exercise, nutrition, stress, social experiences, and environment, with dotted lines pointing to the DNA. On the right, an arrow labeled “gene expression” points to a glowing symbol, and the text at the bottom reads “Not changing the DNA, but the instructions.” This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Why are you the way you are? Part of the answer is in your genes, the instructions you inherited from your parents. But genes aren’t the whole story. Your experiences, from the food you ate as a baby to the people who cared for you, help decide how those instructions get used.

In this module, you’ll learn how genes and evolution shape behavior, how experiences can turn genes on or off (a field called **epigenetics**), and how your brain grows from a tiny tube of cells into an adult brain. You’ll also see that the brain keeps changing your whole life. That ability to change is called **neuroplasticity**.

Some of these topics may feel personal. That’s okay. The big message of this module is a hopeful one: your past shapes you, but it doesn’t lock you in.

Learning Objectives

By the end of this module, you will be able to:

- Describe how genes, chromosomes, and DNA relate to one another.
- Explain how twin and adoption studies separate the effects of genes and environment, and what heritability does and doesn’t tell us.
- Explain in plain terms how DNA methylation and histone changes turn genes on or off without changing the DNA.
- Give examples of how early care and nutrition can affect gene activity and later health.
- Describe the main steps of brain development, from the neural tube to synaptic pruning and myelination.
- Explain how experience changes connections between neurons.
- Compare sensitive periods and critical periods, with examples.

Unit 4.1: Introduction to Genes, Development, and Plasticity
Unit 4.2: Genes, Evolution, and Behavior
Unit 4.3: The Epigenome: Turning Genes On and Off
Unit 4.4: Early Childhood Experience
Unit 4.5: Child Nutrition and the Epigenome
Unit 4.6: How the Brain Develops
Unit 4.7: Neuroplasticity and Sensitive Periods
Unit 4.8: Module Wrap-Up
Unit 4.9: References

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Unit 4.1: Introduction to Genes, Development, and Plasticity

Learning Objectives

By the end of this unit, you will be able to:

- Explain how genes and experiences work together to shape who you are.
- Give an example of why identical twins can turn out different.

Understanding the brain and behavior can feel overwhelming, especially when it comes to genetics and biology. Here's the good news: you don't need to memorize complicated terms to understand the big picture.

In this module, we'll look at how your genes and your experiences work together. Some things, like eye color, are set mostly by your genes. Others, like the language you speak, come almost entirely from your environment. Most of what makes you *you* comes from both, working together over time.

Experiences, especially in childhood, can affect how your brain and body develop. That doesn't mean your DNA (deoxyribonucleic acid) is changing. What changes is how your body uses the instructions written in your DNA. That's why even identical twins can grow up to be different in health and behavior.



> **Image description:** An artistic image of a woman in profile with a glowing, colorful brain and a strand of DNA inside her head. On the left, dark and stormy, a child sits alone by a rainy window, and puzzle pieces read "stress" and "trauma." On the right, in warm sunset light, a parent hugs a child, friends sit together, and arrows labeled "love," "nutrition," "support," "safe environment," and "positive experiences" point toward her. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

We'll also follow the brain as it grows, before and after birth, and see how it keeps rewiring itself as you learn. If a term ever confuses you, come back to the big idea: your brain is shaped by more than just your genes, and it can keep changing at any age.

From a Peer

"When I first heard 'genetics,' I thought it meant everything about me was already decided. Learning that my experiences matter too, and that my brain can still change, made me want to keep going."

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Unit 4.2: Genes, Evolution, and Behavior

Learning Objectives

By the end of this unit, you will be able to:

- Describe the relationship among DNA, chromosomes, and genes, and distinguish genotype from phenotype.
- Explain how mutations and natural selection shape traits and behavior, including in human evolution.
- Explain what twin and adoption studies and heritability can and can't tell us.

Ever been told you have your mom's laugh or your grandpa's temper? Some of that is learned, and some may come from genes. How do scientists tell?

Genes, Chromosomes, and DNA

Almost every cell in your body holds a full set of instructions written in **DNA** (deoxyribonucleic acid). The DNA is packed into 46 **chromosomes**, in 23 pairs. You got one chromosome of each pair from each parent. A **gene** is a stretch of DNA that carries the instructions for making a protein. Many genes come in slightly different versions, so people differ.

In Plain Words

Think of your DNA as a huge family recipe book. Each chromosome is one volume, and each gene is a single recipe. Everyone has the same kinds of recipes, but small differences in the wording change how the dish turns out.

Your **genotype** is your genetic makeup. Your **phenotype** is what you can actually observe, like height, eye color, or behavior. Phenotype comes from genes and environment together. A few conditions come from a single gene. For example, phenylketonuria (PKU) can harm brain development, but a special diet started soon after birth prevents most of the harm, which is why newborns are tested for it. Most traits, like height, intelligence, and the risk for depression, are shaped by many genes, each with a tiny effect.

Evolution and Behavior

Genes can change through **mutations**, permanent changes in the DNA. Most do nothing or cause harm, but a few help. Through **natural selection**, traits that help living things survive and have children become more common over many generations. A classic example: carrying one copy of the sickle-cell gene helps protect against malaria, so it is more common where malaria is common. Carrying two copies causes sickle-cell disease.

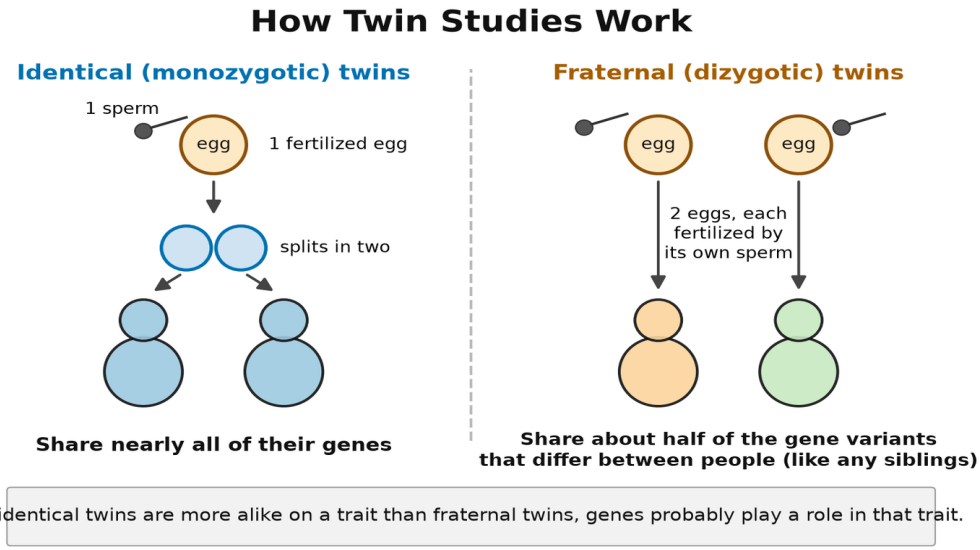
Natural selection shapes brains and behavior too, such as how quickly we notice danger. Evolution explains where a tendency came from, not whether it is good, and it doesn't mean behavior is fixed. Also, the outward traits used to sort people into races are a tiny part of our DNA. There is more genetic variation *within* any racial group than *between* groups (Yudell et al., 2016).

Natural selection also shaped our own species. *Homo sapiens* evolved in Africa about 300,000 years ago, during a time of dramatic climate change (Smithsonian National Museum of Natural History, n.d.-a). Over the course of human evolution, brain size tripled. It grew fastest between about 800,000 and 200,000 years ago, when the climate swung widely, and a bigger brain that could handle new information helped our ancestors survive (Smithsonian National Museum of Natural History, n.d.-b). Today the human brain averages about 1,300 cubic centimeters, the largest and most complex of any living primate (Smithsonian National Museum of Natural History, n.d.-a, n.d.-b).

Twin and Adoption Studies

Scientists can't assign babies to families at random, so they use natural experiments. In adoption studies, they ask whether

children resemble the parents who raised them or the parents who gave birth to them. In twin studies, they compare two kinds of twins. **Identical twins** (monozygotic) come from one fertilized egg and share nearly all their genes. **Fraternal twins** (dizygotic) come from two eggs and, like any siblings, share about half of the gene variants that differ between people. The diagram below shows how the two kinds of twins form.



> **Image description:** A two-part diagram titled “How Twin Studies Work.” On the left, identical (monozygotic) twins come from one fertilized egg that splits in two, so they share nearly all of their genes. On the right, fraternal (dizygotic) twins come from two separate eggs and two sperm, each fertilized by its own sperm, so, like any brothers and sisters, they share about half of the gene variants that differ between people. A note at the bottom says that if identical twins are more alike on a trait than fraternal twins, genes probably play a role in that trait.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

If identical twins are more alike on a trait than fraternal twins are, genes probably matter for that trait. Height works this way. Spoken language doesn’t: both kinds of twins raised together speak the same language as their family. Studies like these give a number called **heritability**, how much of the *differences* between people in a group are linked to differences in their genes. Heritability describes groups, not individuals, and it can change when environments change.

Genes and environment also work together. In **gene–environment interaction**, a gene matters in some environments but not others. For example, adopted children whose birth mothers had schizophrenia were much more likely to develop schizophrenia or a related disorder if they were raised in a stressful, disrupted home than in a healthy one (Tienari et al., 2004).

Check Your Understanding

1. How many chromosomes do most human cells have?
2. What is the difference between genotype and phenotype?
3. How do identical twins differ genetically from fraternal twins?
4. What does heritability describe: individuals or groups?

The answers are in the unit you just read.

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Unit 4.3: The Epigenome: Turning Genes On and Off

Learning Objectives

By the end of this unit, you will be able to:

- Define epigenetics and gene expression.
- Describe how DNA methylation and histone modification turn genes up or down.
- Give an example of how experience can change gene expression without changing DNA.

Almost every cell in your body has the same DNA. So why does a skin cell act so differently from a brain cell? Because each cell uses only the genes it needs and keeps the rest switched off.

Gene expression is the process of using a gene's instructions to make a protein. **Epigenetics** is the study of changes in gene expression that don't change the DNA sequence itself. The chemical tags and packaging that control which genes are used make up the **epigenome**. Your experiences, including stress, care, and nutrition, can change the epigenome.

In Plain Words

Think of your genes as light switches, or better, dimmer switches. The wiring (your DNA) stays the same. Epigenetic changes turn the lights up, down, on, or off, depending on what the cell needs and what's going on around you.

How DNA Is Packed

Inside each cell, DNA is wrapped around spool-like proteins called **histones**, like thread wound around spools. When the DNA is wrapped loosely, the cell can reach a gene and use it. When it's wrapped tightly, the gene is hard to reach and usually stays quiet. The infographic below shows how experiences can change how tightly genes are wrapped.

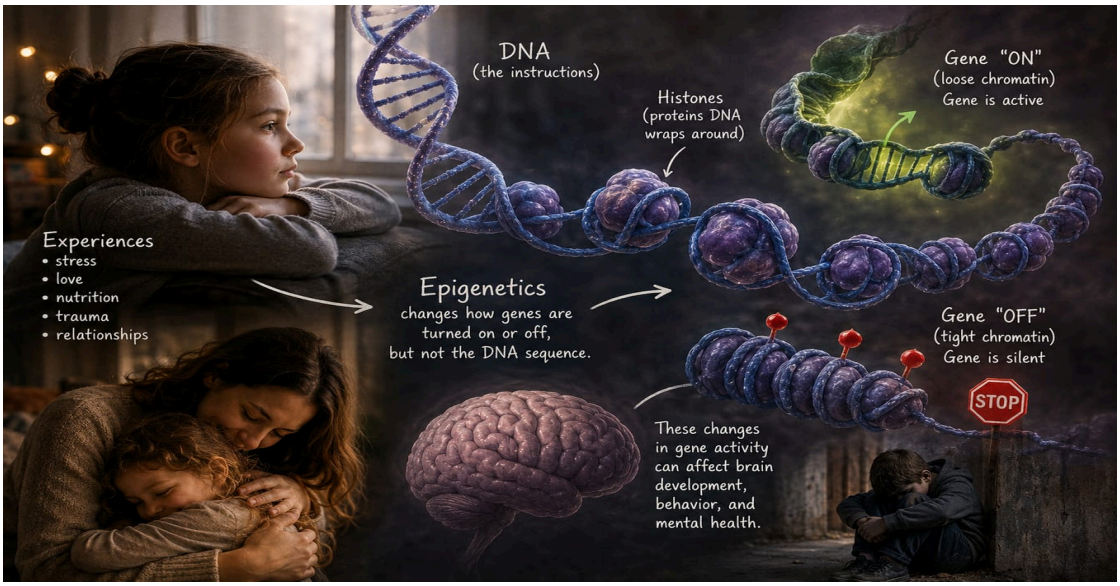


Image description: An infographic showing how experiences such as stress, love, nutrition, trauma, and relationships lead to epigenetic changes, which change "how genes are turned on or off, but not the DNA sequence." A strand of DNA ("the instructions") wraps around ball-shaped proteins called histones ("proteins DNA wraps around"). Where the wrapping is loose, the label reads "Gene 'ON' (loose chromatin): gene is active." Where it is

> tight and marked with small red tags, the label reads “Gene ‘OFF’ (tight chromatin): gene is silent.” A note says these changes in gene activity can affect brain development, behavior, and mental health.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Two Main Switches

In **DNA methylation**, small chemical tags called methyl groups attach to the DNA. In the right spot, they usually act like a stop sign, so the gene isn’t used. In **histone modification**, chemical tags attach to the histones and loosen or tighten the DNA’s wrapping, making genes more or less active.

These switches matter a lot in the brain, where genes must turn on and off at the right times for development and learning. And research shows that life experiences, especially in early childhood, can change both kinds of switches.

From a Peer

“I always thought I just wasn’t smart enough for science. Learning that childhood stress can affect focus and memory helped me see I wasn’t broken. My brain had adapted to what it went through, and that gave me the confidence to keep going and ask for help in class.”

Key Takeaways

- Epigenetics changes how genes are used, not the DNA itself.
- DNA wraps around histones: loose wrapping lets genes be used, and tight wrapping keeps them quiet.
- DNA methylation usually turns genes off, and histone changes can turn them up or down.
- Experiences, especially early ones, can change these switches.

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Unit 4.4: Early Childhood Experience

Learning Objectives

By the end of this unit, you will be able to:

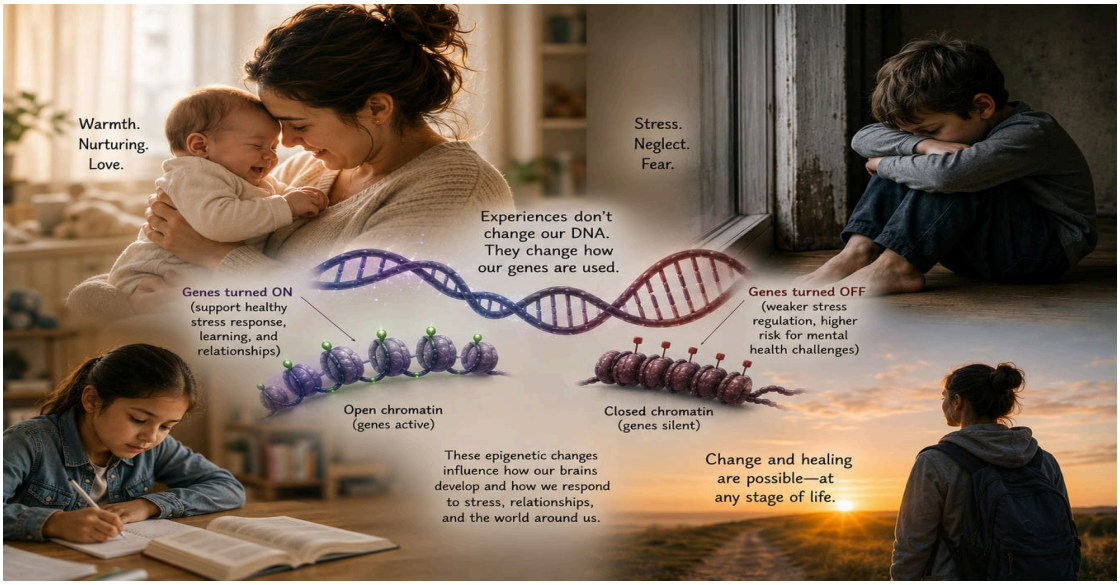
- Describe what studies of rat mothers' licking and grooming showed about stress and glucocorticoid receptors.
- Explain how early experiences in people may affect the stress system.
- Define resilience and give examples of what builds it.

Our earliest experiences have a powerful effect on how the brain and body develop. When a child gets warmth, steady attention, and physical comfort, it helps shape the brain's ability to handle stress, learn, and build healthy relationships. When early life is stressful, neglectful, or harmful, it can leave lasting biological effects.

What Rat Mothers Taught Us

Some of the clearest evidence comes from rats. Rat mothers differ in how much they lick and groom their pups. Pups that got a lot of licking and grooming in their first week of life grew up handling stress better. As adults, they had more **glucocorticoid receptors** in the hippocampus. These receptors detect the stress hormone **cortisol** (corticosterone in rats) and help switch off the stress response once a threat is over (Weaver et al., 2004).

Pups that got little licking and grooming had fewer of these receptors and stayed in "stress mode" longer. Researchers traced the difference to epigenetic changes: more DNA methylation and less histone acetylation on the receptor gene, which kept it quieter. When adult rats were given a drug that changes histone tags, the difference largely went away (Weaver et al., 2004). Early experience shapes the brain in powerful ways, but the switches can still change later. The infographic below contrasts warm, nurturing care with stress and neglect.



> **Image description:** An infographic split into two sides. On the left, labeled "Warmth. Nurturing. Love.," a mother holds a smiling baby and a girl studies. On the right, labeled "Stress. Neglect. Fear.," a boy sits alone with his head on his knees. In the middle, text reads "Experiences don't change our DNA. They change how our genes are used." Open chromatin is labeled "Genes turned ON (support healthy stress response, learning, and relationships)," and closed chromatin is labeled "Genes turned OFF (weaker stress regulation, higher risk for mental health challenges)." At the bottom right, a young person walks toward a sunrise beside the words "Change and healing are possible, at any stage of life."

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

What About People?

Similar patterns show up in humans. In brain tissue from people who died by suicide, those who had been abused as children had more methylation of the glucocorticoid receptor gene than those who had not (McGowan et al., 2009). Other studies link childhood adversity to methylation changes in blood samples, though results vary. Changes like these may help explain why early trauma raises the risk of depression, anxiety, and trouble managing stress.

Epigenetics doesn't mean destiny. Some epigenetic marks can change again later in life, and the brain keeps adapting. Supportive relationships, therapy, good nutrition, and education all help people build **resilience**, the ability to recover and adapt after stress or adversity.

From a Peer

"Where I grew up, you learned not to cry and not to ask for help. Reading about the rat pups was the first time anyone explained what had happened to my nervous system. I wasn't messed up. I adapted the only way I could, and I can keep changing."

Check Your Understanding

1. In the rat studies, what did more licking and grooming lead to as adults?
2. What do glucocorticoid receptors help do?
3. What happened to the receptor gene in pups that got little care?
4. What is resilience?

The answers are in the unit you just read.

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Unit 4.5: Child Nutrition and the Epigenome

Learning Objectives

By the end of this unit, you will be able to:

- Define nutritional epigenetics.
- Describe what evidence from animals and people, such as the Dutch Hunger Winter, shows about early nutrition.
- Give examples of programs that support healthy development.

Most of us were told to “eat your veggies.” It might have sounded like adult talk, but science shows that food, even food eaten before we were born, can affect how our genes work.

Nutritional epigenetics is the study of how diet changes gene expression. Food doesn’t rewrite your genes, but it supplies the raw materials for the chemical tags that turn genes up, down, on, or off. These changes can affect how the body and brain develop and the long-term risk of diseases like diabetes and heart disease. The artistic image below shows how nutrition connects generations.



Image description: An artistic image about nutrition across generations. On the left, a pregnant woman holds her belly, where a developing baby glows. In the middle, a glowing strand of DNA is surrounded by floating ball-shaped proteins with small colored tags. On the right, a boy eats a bowl of vegetables and a woman jogs outdoors. The front is filled with healthy foods such as leafy greens, berries, salmon, broccoli, peppers, nuts, and avocado. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Evidence from Animals and People

When pregnant rats ate a diet low in certain nutrients called methyl donors (found in foods like leafy greens, beans, and eggs), their pups showed changes in the tags on some genes in the brain and liver, making those genes more active than normal. The changes were tied to what the mother ate during pregnancy.

In people, some of the clearest evidence comes from the Dutch Hunger Winter of 1944–1945, when a wartime famine left pregnant women with very little food. Years later, their children had higher rates of heart disease, obesity, and type 2 diabetes, even when

they were born at a normal weight (Roseboom, 2019). About 60 years after the famine, those exposed early in the womb had different methylation on certain genes than their brothers and sisters who weren't (Heijmans et al., 2008).

Fun Fact

The egg cell that became you formed inside your mother while she was still a fetus inside your grandmother. So your grandmother's health during pregnancy may have touched three generations at once. Whether epigenetic tags themselves pass down through generations in humans is still being studied.

Nutrition in early life helps set the stage for lifelong health, but nothing is set in stone. The body keeps adapting, and better food, less stress, and a healthier environment at any age can support health and resilience.

Close to Home

Valley farms grow fresh food for the whole country, yet many families here, including the farmworker families who harvest it, don't always have steady access to it. Long shifts, cost, and distance to a full grocery store all play a role. Programs that help families with young children get healthy food, like WIC (the Special Supplemental Nutrition Program for Women, Infants, and Children) and campus food pantries, are one way communities support healthy development.

Key Takeaways

- Food can change gene activity without changing the DNA.
- Famine before birth was linked to later health problems and lasting methylation differences.
- Early nutrition sets the stage, but healthy changes help at any age.

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Unit 4.6: How the Brain Develops

Learning Objectives

By the end of this unit, you will be able to:

- Describe how the neural tube forms and why folic acid matters early in pregnancy.
- Explain neurogenesis, neuronal migration, apoptosis, synaptic pruning, and myelination.
- Explain why the prefrontal cortex is among the last brain areas to mature.

Your brain started as a flat sheet of cells smaller than a grain of rice. Today it holds about 86 billion neurons. How did that happen?

From Neural Tube to Brain

About three weeks after conception, a strip of cells on the embryo's back folds inward and closes into the **neural tube**, usually by the end of the fourth week. The front end becomes the brain, and the rest becomes the spinal cord. Because this happens so early, often before a person knows they are pregnant, health experts recommend that anyone who could become pregnant get enough folic acid, a B vitamin that helps prevent neural tube defects such as spina bifida (Centers for Disease Control and Prevention, 2026).

By the end of the fourth week, the front of the tube swells into the three regions you met in Unit 2.6: the forebrain, midbrain, and hindbrain.

Building and Wiring Neurons

Next comes **neurogenesis**, the birth of new neurons. Most of the neurons in your cortex were made before you were born. New neurons then travel to their final spots in a process called **neuronal migration**, many of them climbing along long glial cells like ropes. Once in place, they grow axons and dendrites and form synapses with each other.

The brain also makes more neurons than it needs. Extra neurons that don't form useful connections die off in a planned, tidy process called **apoptosis** (programmed cell death). This is a normal part of building a healthy brain.

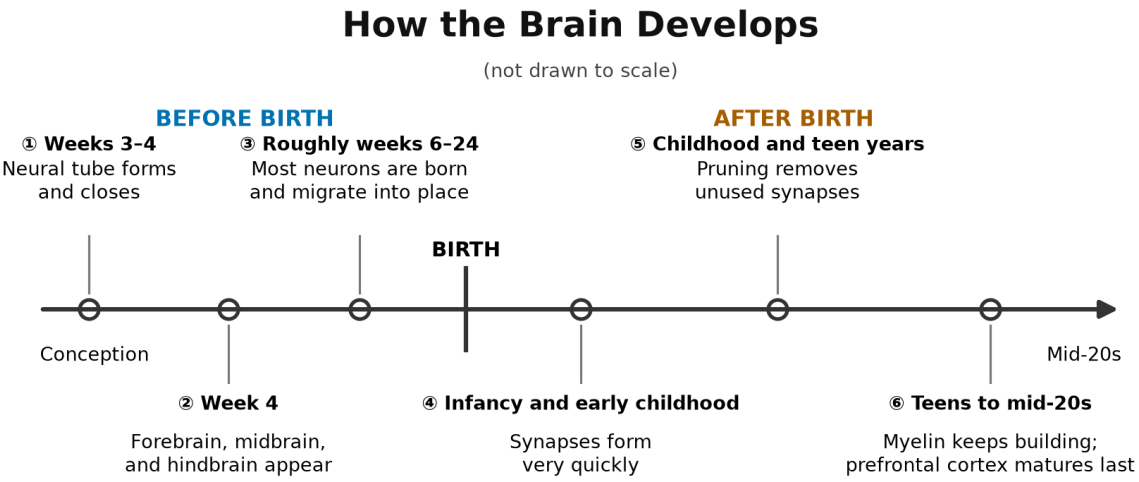


Image description: A timeline titled "How the Brain Develops," running from conception to the mid-20s. Before

> birth: the neural tube forms and closes (weeks 3–4); the forebrain, midbrain, and hindbrain appear (week 4); and most neurons are born and migrate to their places (roughly weeks 6–24). After birth: synapses form very quickly in infancy and early childhood; pruning removes unused synapses through childhood and the teen years; and myelin keeps building, with the prefrontal cortex maturing last, into the mid-20s. The timeline is not drawn to scale.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Pruning and Myelin

After birth, synapses form at an amazing pace, so a toddler's brain has far more synapses than an adult's. Then **synaptic pruning** removes the connections that aren't used, while the ones that are used get stronger. Different areas follow different timelines. Pruning in areas for vision and hearing happens early, while pruning in the prefrontal cortex continues through the teen years (Huttenlocher & Dabholkar, 1997).

At the same time, **myelination**, the wrapping of axons in fatty myelin, speeds up signals. Myelin keeps building through adolescence and into early adulthood.

The Teen and Young Adult Brain

The **prefrontal cortex**, at the front of the frontal lobe, handles planning, self-control, and weighing risks. It is one of the last areas to mature, continuing into the early to mid-20s (Giedd, 2004). Meanwhile, reward areas are very active in the teen years. That mix helps explain why teens tend to seek new experiences and take risks. Taking some risks also helps teens build independence and decision-making skills.

In Plain Words

Picture building a car where the gas pedal is installed early and the brakes are installed last. Teens have a strong gas pedal (reward and excitement) while the brakes (the prefrontal cortex) are still being finished.

Check Your Understanding

1. What structure forms in the first month and becomes the brain and spinal cord?
2. Which B vitamin helps prevent neural tube defects?
3. What is synaptic pruning?
4. Which brain area is one of the last to mature?

The answers are in the unit you just read.

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Unit 4.7: Neuroplasticity and Sensitive Periods

Learning Objectives

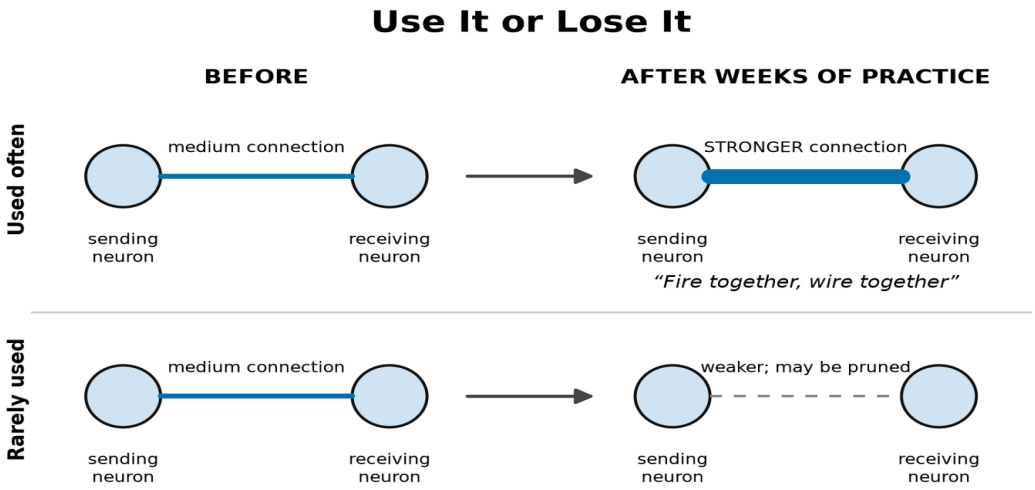
By the end of this unit, you will be able to:

- Explain how long-term potentiation supports the idea that “neurons that fire together, wire together.”
- Distinguish sensitive periods from critical periods.
- Give examples of plasticity at any age, such as cross-modal plasticity and recovery after a stroke.

Every time you learn something new, like a song, a recipe, or a math step, your brain physically changes. Neuroplasticity is the brain’s ability to rewire its connections in response to experience. It is strongest in childhood, but it never switches off.

Fire Together, Wire Together

In 1949, psychologist Donald Hebb proposed that when two neurons are active at the same time again and again, the connection between them gets stronger. This idea is often summed up as “neurons that fire together, wire together.” Later, researchers found a way it happens: **long-term potentiation** (LTP), a lasting strengthening of a synapse after repeated use (Bliss & Lømo, 1973). Connections that are rarely used can weaken and be pruned. Strengthening some links and weakening others lets the brain store what you learn. The diagram below shows this “use it or lose it” idea.



> **Image description:** A diagram titled “Use It or Lose It.” Two rows each show a sending neuron connected to a receiving neuron, before and after weeks of practice. In the top row, the two neurons are active together again and again, and the connection becomes thicker and stronger (labeled “fire together, wire together”). In the bottom row, the connection is rarely used, so it becomes thinner and weaker and may be pruned away, shown with a dashed line. A note explains that line thickness shows connection strength.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

New Neurons in Adults?

For a long time, scientists believed adults never make new neurons. Then a 1998 study found new neurons in the adult human hippocampus (Eriksson et al., 1998). This process is called **adult neurogenesis**. How much it happens in people is still debated.

One study estimated about 700 new neurons a day in each hippocampus (Spalding et al., 2013), while another found almost none in adults (Sorrells et al., 2018).

Sensitive and Critical Periods

Some experiences matter most at certain ages. During a **sensitive period**, experience has an especially strong effect on the brain, but learning is still possible later. During a **critical period**, missing a key experience can have effects that are hard or impossible to undo.

Vision has a critical period. When kittens had one eye covered during an early window, that eye never regained normal vision, because the brain gave its space to the open eye (Hubel & Wiesel, 1970). This is one reason doctors treat a child's "lazy eye" early. In people born blind, the visual cortex starts responding to touch and sound instead, a change called **cross-modal plasticity** (Merabet & Pascual-Leone, 2010).

Learning a second language looks more like a sensitive period. People who moved to the United States and started learning English before about age 7 tended to reach native-like grammar, while those who started later usually did less well (Johnson & Newport, 1989). Adults still learn languages. It just usually takes more effort.

Close to Home

Many Valley families speak Spanish at home, and kids often pick up English at school without much effort. Their parents and grandparents may study for years and still have an accent. That's a sensitive period at work, not a lack of effort or ability. And adults who keep practicing do keep improving.

Change at Any Age

Plasticity also helps the brain recover. After a stroke, nearby brain areas can take over some lost functions, and rehabilitation works partly by retraining these circuits (National Institute of Neurological Disorders and Stroke, 2023). Whether you're starting college right after high school, coming back after years of work, or taking classes as a Rising Scholars student, every new skill you practice is your brain rewiring itself.

From a Peer

"I came back to school in my 30s and thought my brain was too old to learn. Now I know every time I practice something hard, I'm literally building new connections."

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Unit 4.8: Module Wrap-Up

You made it through Module 4. Before you move on to vision and how your brain builds the world you see, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Your genes and your experiences work together to shape who you are, and experiences can change how your body uses its DNA instructions without changing the DNA itself, which is one reason identical twins can turn out different (4.1).
- Your DNA is packed into 46 chromosomes, a gene is a stretch of DNA that carries instructions for making a protein, and your phenotype, the traits people can observe, comes from your genotype and your environment together (4.2).
- Mutations and natural selection shape traits and behavior over many generations, and over the course of human evolution our brain tripled in size, but evolution explains where a tendency came from, not whether it is good, and it doesn't mean behavior is fixed (4.2).
- Twin and adoption studies help separate the effects of genes and environment, and heritability describes differences within a group, not any one person, and can change when environments change (4.2).
- Epigenetics is the study of changes in how genes are used that don't change the DNA itself, and chemical tags such as DNA methylation and histone changes work like dimmer switches that turn genes up, down, on, or off (4.3).
- Rat pups that got more licking and grooming grew up handling stress better because of epigenetic changes to a stress-hormone receptor gene, and in people, early trauma isn't destiny, because support, therapy, and education help build resilience (4.4).
- Nutrition, even before birth, can change how genes work, as the Dutch Hunger Winter showed, and programs like WIC help families with young children get healthy food (4.5).
- The brain grows from the neural tube, which is why folic acid matters early in pregnancy, and the prefrontal cortex is one of the last areas to mature, continuing into the early to mid-20s (4.6).
- Neurons that fire together wire together through long-term potentiation, some experiences matter most during sensitive or critical periods, and the brain keeps rewiring itself at any age (4.7).

Why This Module Matters

This module carries a hopeful message: your past shapes you, but it doesn't lock you in. Hard early experiences, like ongoing stress or not having steady access to fresh food, can leave biological marks. Many Valley families, including the farmworker families who grow food for the whole country, know these challenges firsthand. But supportive relationships, good nutrition, therapy, and education all help people build resilience. And whether you're starting college right after high school, coming back after years of work, or taking classes as a Rising Scholars student, every new skill you practice is your brain rewiring itself.

Module 4 ideas in everyday life

Idea	Where you met it	Where you might see it
Genes and environment together	4.1, 4.2	Being told you have your mom's laugh or your grandpa's temper: some of that is learned, and some may come from genes
Epigenetics and resilience	4.3, 4.4	Understanding that early stress may have shaped how your body handles stress, and that it can still change
Nutritional epigenetics	4.5	WIC and campus food pantries helping families with young children get healthy food
Folic acid	4.6	Health advice that anyone who could become pregnant should get enough folic acid
Sensitive period	4.7	Kids picking up English at school while their parents and grandparents study for years and still have an accent
Plasticity at any age	4.7	Coming back to school as an adult and building new connections every time you practice

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Think of a trait you share with a family member, like a laugh, a talent, or a temper. How much of it do you think comes from genes, and how much from growing up together?
2. This module says your past shapes you but doesn't lock you in. What is one experience that shaped you, and what are you doing now that keeps you growing?
3. Who or what has helped you bounce back after a hard time? How could you build more of that support into your life now?
4. Think of a skill you are learning now. How does knowing about neuroplasticity change the way you think about practicing it?

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Unit 4.9: References

About This Module

This module was adapted and rewritten by Michael Miguel from Chapters 7 and 9 of *Biological Psychology* by Michael J. Hove and Steven A. Martinez (ROTEL Project, 2024), licensed CC BY-NC-SA 4.0, and from Michael Miguel's earlier Epigenetics module. Changes: rewritten in plain, conversational language for Coalinga College campus and Rising Scholars students, with Central Valley examples, plain-language explainers, review questions, three new units (4.2, 4.6, and 4.7), and new or AI-generated images. Terms are defined in the book Glossary.

The ROTEL chapters were adapted in part from:

Betts, J. G., Young, K. A., Wise, J. A., Johnson, E., Poe, B., Kruse, D. H., Korol, O., Johnson, J. E., Womble, M., & DeSaix, P. (2022). *Anatomy and physiology* (2nd ed.). OpenStax. https://openstax.org/details/books/a...-physiology-2e. Licensed CC BY 4.0.

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Spielman, R. M., Jenkins, W. J., & Lovett, M. D. (2020). *Psychology* (2nd ed.). OpenStax. https://openstax.org/books/psychology-2e. Licensed CC BY 4.0.

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MODULE 5: VISION AND PERCEPTION



> **Image description:** An artistic poster titled “Vision & Perception: How we see and make sense of the world around us.” On the left is a close-up of a person’s eye. Light from a mountain lake scene enters a cut-away eyeball, and a glowing line carries signals to the back of a brain. Labels read “Light enters the eye,” “Signals travel to the brain,” and “Visual cortex processes information.” This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Open your eyes and the world is just *there*: colors, faces, movement, depth. It feels effortless, but it isn’t. Your eyes catch light, and your brain does the hard work of turning that light into a picture of the world.

In this module, you’ll follow light from the front of your eye to the back of your brain. Then you’ll see that vision rarely works alone. Your brain blends sight with hearing, touch, and balance, and sometimes that blending creates illusions that reveal how perception really works.

Learning Objectives

By the end of this module, you will be able to:

- Identify the main parts of the eye and describe what rods and cones do.
- Explain why contrast matters in vision and how lateral inhibition sharpens edges.
- Trace the path of visual signals from the retina to the primary visual cortex, and compare the “what” and “where/how” streams.
- Explain how two eyes help you judge depth.
- Distinguish sensation from perception, and multimodal from crossmodal effects.
- Describe the superadditive effect and the principle of inverse effectiveness.
- Give examples of multisensory illusions, including the rubber hand illusion and the McGurk effect.

Unit 5.1: Introduction to Vision

Unit 5.2: The Eye and the Importance of Contrast

Unit 5.3: From Eye to Brain

Unit 5.4: Introduction to Perception

Unit 5.5: When Senses Work Together
Unit 5.6: Sight, Touch, and Body Ownership
Unit 5.7: Seeing Speech
Unit 5.8: Module Wrap-Up
Unit 5.9: References

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Unit 5.1: Introduction to Vision

Learning Objectives

By the end of this unit, you will be able to:

- Explain why the brain, not just the eyes, builds what you see.
- Give an example of the brain filling in or filtering visual information.

Most of us don't think about how we see. We open our eyes, and there it is: color, movement, light, faces. But vision is one of the most complex systems in the body. It's not just about having working eyes. It's about how your brain takes light and builds a whole world from it.

You've probably heard "seeing is believing," but what you see isn't always what's really there. Your brain fills in blanks, ignores distractions, and filters out what it thinks you don't need. This part of the module will help you think differently about what it means to "see."

Here's what we'll explore:

- Which parts of the eye catch light
- Why contrast, not brightness, is what your eyes care about most
- How signals travel from your eyes to your brain
- Why two eyes help you judge depth

You don't need to memorize every part of the eye to get the big ideas. What matters is how your eyes and brain work together to help you move through your world. If you've worn glasses since childhood, struggled with night driving, or wondered why your phone screen is hard to read in the sun, this section will start to make sense of all that. The artistic image below shows light traveling from the eye to the back of the brain.



> **Image description:** An artistic image of a woman's eye with a beam of light entering it. A cut-away eyeball sends a glowing signal to the back of a brain, and a city park scene glows beyond it. Small panels along the bottom are labeled "Dim light vision" (a dark road at night), "Color sensitivity" (a blue eye), "Depth perception" (a hand reaching for a mug), and "Focusing attention" (one person highlighted in a crowd). A hand at the right holds up glasses that sharpen part of the scene. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

From a Peer

"I always thought my eyes were like a camera. Finding out my brain is doing most of the work, and even filling in what's missing, kind of blew my mind."

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Unit 5.2: The Eye and the Importance of Contrast

Learning Objectives

By the end of this unit, you will be able to:

- Describe how light becomes nerve signals in the retina, and compare rods and cones.
- Explain why each eye has a blind spot.
- Explain how lateral inhibition sharpens contrast and how dark adaptation works.

You might think your eyes work like a camera, taking pictures and sending them to your brain. That's not quite how it works. Let's start with the eye itself.

How the Eye Catches Light

Light first passes through the cornea, the clear front of the eye. It then goes through the pupil, an opening whose size is set by the colored iris. The lens focuses the light onto the **retina**, a thin layer of tissue lining the back of the eye.

The retina holds the **photoreceptors**, cells that turn light into nerve signals. **Rods** work best in dim light. **Cones** work best in bright light and let you see color and fine detail. Cones are packed into the **fovea**, the center of the retina, which is why you see most sharply where you look straight ahead. Signals leave the eye through the **optic nerve**. Where it exits, there are no photoreceptors, so each eye has a **blind spot**. You don't notice it because your brain fills in the gap and your other eye covers it.

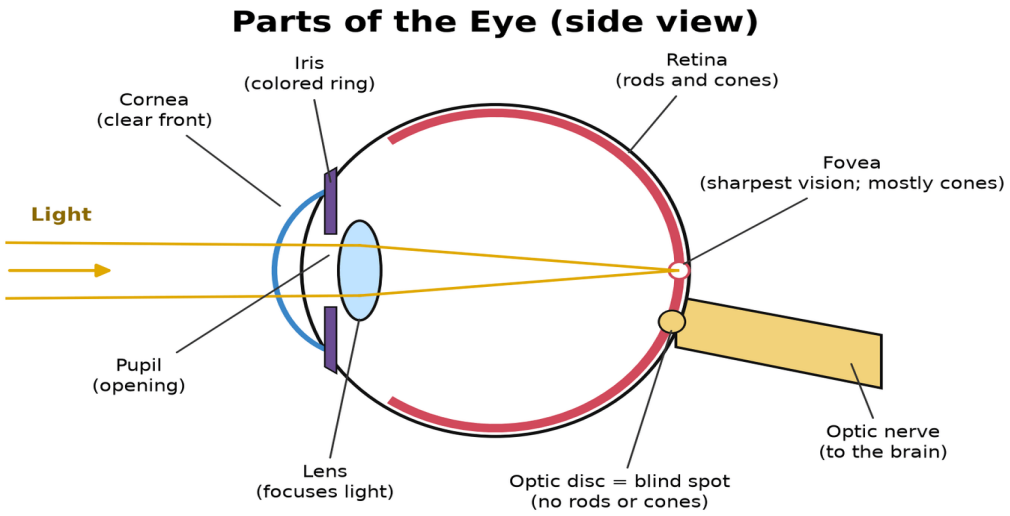


Image description: A side view of the eye, with the front of the eye on the left. Light enters through the clear cornea, passes through the pupil (the opening in the colored iris), and is focused by the lens onto the retina, the thin layer lining the back of the eye. The fovea, a small pit in the center of the retina, is packed with cones and gives the sharpest vision. The optic nerve leaves the back of the eye at the optic disc, which has no rods or cones and creates the blind spot.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Why Contrast Matters

Your eyes and brain care less about the total amount of light than about **contrast**, the difference in light between nearby spots. Look at your hand on a desk. You can tell where your hand ends because of the difference between light bouncing off your skin and light bouncing off the desk. A sudden change in light can mean something important, like a person walking by, so your brain responds to changes first.

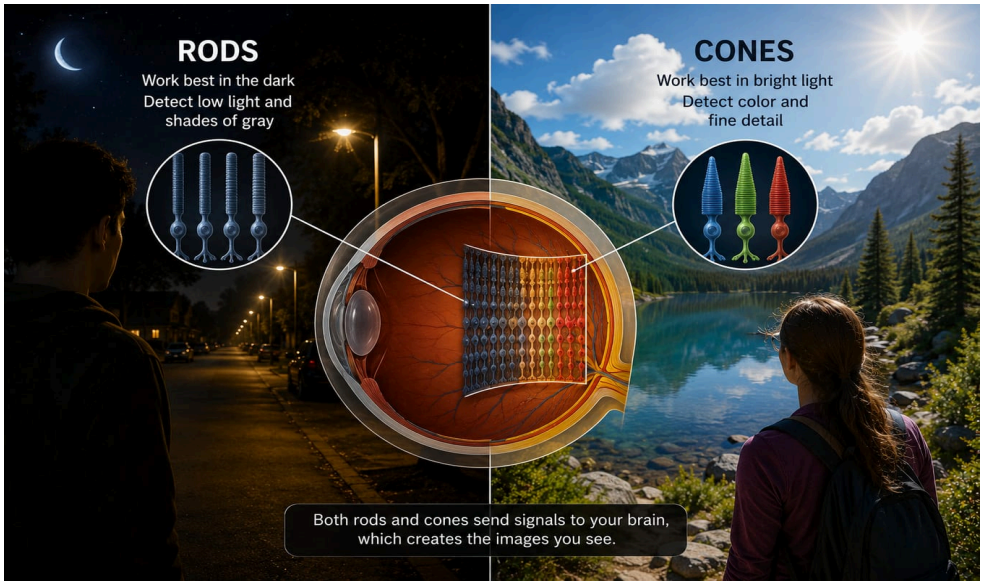
Your visual system even exaggerates contrast through **lateral inhibition**. When a cell is strongly activated by light, it quiets its neighbors. Cells right at an edge get less of this quieting from the dark side, so edges, like the border between shade and sunlight, stand out more.

Close to Home

Valley drivers know tule fog. Fog scatters light, so the edges of cars and lane lines lose contrast, and your visual system has less to work with. That's why slowing down and using low-beam headlights helps.

Adjusting to Light and Dark

Walk out of a dark movie theater into bright sun and you're dazzled for a moment. Your rods are overwhelmed, but your cones take over within seconds. Going the other way is slower. After you turn off the lights, it can take 20 to 30 minutes for your rods to fully recover and your eyes to reach full sensitivity, a process called **dark adaptation**. That's why you bump into furniture at first.



> **Image description:** An infographic split between night and day. On the left, a person stands on a dark street, under the label "Rods: work best in the dark; detect low light and shades of gray," with a close-up of gray, rod-shaped cells. On the right, a hiker looks at a sunny mountain lake, under the label "Cones: work best in bright light; detect color and fine detail," with a close-up of blue, green, and red cone-shaped cells. In the middle, a cut-away eye shows both kinds of cells in the retina. A caption reads "Both rods and cones send signals to your brain, which creates the images you see."

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Check Your Understanding

1. Which part of the eye focuses light onto the retina?
2. Which photoreceptors work best in dim light?

3. Why does each eye have a blind spot?
4. About how long can full dark adaptation take?

The answers are in the unit you just read.

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Unit 5.3: From Eye to Brain

Learning Objectives

By the end of this unit, you will be able to:

- Trace the path of visual signals from the eye to the primary visual cortex.
- Compare the ventral (“what”) and dorsal (“where/how”) streams.
- Explain how binocular disparity supports depth perception.

Seeing doesn’t stop at your eyes. That’s where the story begins. Your brain has to build a picture from the signals it gets: filling gaps, spotting motion, and working out where things are.

The Path to the Visual Cortex

The optic nerves from both eyes meet at the **optic chiasm**, where some fibers cross to the other side. Because of this crossing, what you see on your left is handled by the right side of your brain, and vice versa.

Most signals then go to the **lateral geniculate nucleus** (LGN), a relay station in the thalamus, and on to the **primary visual cortex** (V1) in the occipital lobe at the back of your head. Neurons in V1 respond to simple features, such as edges and lines at certain angles (Hubel & Wiesel, 1962). A smaller branch of the optic nerve skips the thalamus and goes to the **superior colliculus** in the midbrain, which quickly turns your eyes toward sudden movement.

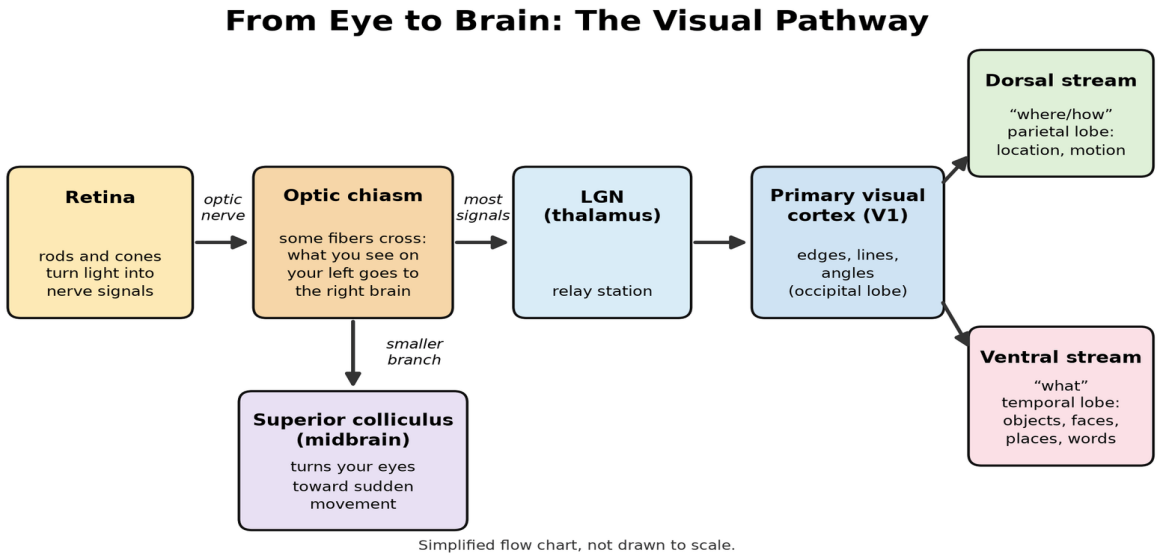


Image description: A flow chart of how visual signals travel. The retina sends signals along the optic nerve to the optic chiasm. Most signals then go to the lateral geniculate nucleus (LGN) of the thalamus and on to the primary visual cortex (V1) in the occipital lobe. A smaller branch goes straight to the superior colliculus in the midbrain, which turns the eyes toward sudden movement. From V1, a ventral “what” stream runs into the temporal lobe to recognize objects, faces, places, and words, and a dorsal “where/how” stream runs into the parietal lobe to track location and motion and guide reaching.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Two Streams: “What” and “Where/How”

From V1, signals split into two main routes. The **ventral stream**, or “what” pathway, runs into the temporal lobe and helps you recognize what you’re looking at. The **dorsal stream**, or “where/how” pathway, runs into the parietal lobe and helps you track where things are and how to reach for them.

Some specialized visual areas

Area	Stream	What it does
Area MT (middle temporal)	Dorsal (“where/how”)	Detects motion, like a car moving
Fusiform face area	Ventral (“what”)	Recognizes faces
Parahippocampal place area	Ventral (“what”)	Recognizes places and scenes
Visual word form area	Ventral (“what”)	Recognizes written words and letters

Why Two Eyes?

Each eye sees the world from a slightly different angle. Your brain compares the two views, called **binocular disparity**, to judge distance. This gives you **depth perception**, the ability to see the world in three dimensions. One eye still gets some depth from clues like shadows and size, but two eyes do it better.

Learning to see takes experience. Michael May lost his sight at age 3. About 40 years later, surgery restored his eye, but he still struggled to recognize faces and judge depth, while he could see motion well (Fine et al., 2003).

From a Peer

“When I started welding, I couldn’t judge how far the tip was from the metal through the dark lens. After a few weeks, I started using shadows and reflections. My eyes were fine. My brain just had to learn.”

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Unit 5.4: Introduction to Perception

Learning Objectives

By the end of this unit, you will be able to:

- Distinguish sensation from perception.
- Define synesthesia and multimodal perception and give an example of each.

Imagine always seeing the letter A as red and the number 3 as yellow, even when they're printed in black ink. You might assume everyone sees it that way, until a friend gives you a strange look.

That experience is called **synesthesia**, when stimulating one sense automatically triggers an experience in another. In grapheme-color synesthesia, letters or numbers have their own consistent colors. Estimates vary, but one large study found that about 4 in 100 people have some type of synesthesia (Simner et al., 2006). It isn't a disorder. It's a reminder that perception happens in the brain. The artistic image below shows four types of synesthesia.



> **Image description:** An artistic image of a young woman with her eyes closed and a glowing brain, surrounded by swirls of color. Four labels name types of synesthesia: "Grapheme-color synesthesia: letters and numbers are always seen in specific colors," beside floating colored letters and numbers; "Sound-color synesthesia," beside musical notes; "Sound-taste synesthesia," beside a lemon, chocolate, a strawberry, and coffee; and "Touch-color synesthesia," beside a hand giving off color. The text at the bottom reads "Synesthesia is a reminder that perception is a construct of the brain, not just what the senses detect." This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

From a Peer

"For me, the weekdays have colors. Monday is blue. Wednesday is orange. It's not something I decide. It's just there. I didn't know it was unusual until I was 20."

Sensation and Perception

Sensation is your sense organs detecting energy, like light hitting your retina. **Perception** is your brain organizing and interpreting those signals into something meaningful, like recognizing a friend's face. The same sensation can lead to different perceptions in different people.

One Event, Many Senses

Say you saw a car crash. You'd see the cars hit, hear the bang, and maybe smell burning rubber. But you wouldn't think, "I saw a crash and heard a crash." You'd just think, "There was a crash." Your brain blends the senses into one event. This is **multimodal perception**: combining information from more than one sense into a single experience.

Scientists used to study the senses one at a time, as if each worked alone. Research now shows they usually work together. In the rest of this module, you'll see how your brain decides which signals belong together, why combining senses helps, and how mismatched signals can fool you.

Close to Home

Some of this research happens close by. Dr. Lorin Lachs, a psychology professor at Fresno State, studies how people combine seeing and hearing speech. He also wrote one of the open textbook chapters this module is adapted from.

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Unit 5.5: When Senses Work Together

Learning Objectives

By the end of this unit, you will be able to:

- Explain how the brain uses place and timing to decide which signals belong together.
- Describe the ventriloquism effect, the superadditive effect, and the principle of inverse effectiveness.
- Explain how the vestibulo-ocular reflex keeps vision steady.

Picture yourself on Main Street in Coalinga. You hear a horn, a conversation across the street, smell food from a taquería, and spot a friend waving, all at once. Somehow, your brain sorts out which sights, sounds, and smells go together.

Which Signals Belong Together?

Your brain uses two main clues: signals that come from the *same place* at the *same time* probably come from the same event. Usually that works. But it can be tricked. In the **ventriloquism effect**, you hear the voice coming from the puppet's moving mouth instead of the performer's. Vision is better at pinpointing location, so it wins.

Scientists separate two kinds of effects. In **multimodal** effects, senses combine to help you perceive one event, like watching lips in a noisy room. In **crossmodal** effects, one sense changes what you perceive in another, like the ventriloquism effect.

Stronger Together

Some neurons respond to more than one sense. In the superior colliculus, certain neurons fire much more to a sight and sound together than you'd expect from adding up their responses to each one alone (Meredith & Stein, 1983). This is the **superadditive effect**.

Combining senses helps most when each sense alone is weak. This is the **principle of inverse effectiveness**. In a quiet library, you can hear a friend fine without watching their mouth. In a loud cafeteria, watching their lips helps a lot. In one classic study, seeing the speaker's face helped people understand words in noise about as much as making the speech 15 decibels louder relative to the noise (Sumby & Pollack, 1954).

From a Peer

"Where I'm living right now, there's noise all day: TVs, doors, people talking over each other. I catch myself watching people's mouths more than I ever used to."

Vision and Balance

Try this. Hold your head still and wave a finger back and forth in front of your eyes. It looks blurry. Now hold your finger still and shake your head side to side. Your finger stays sharp. That's the **vestibulo-ocular reflex**: your inner ear senses your head moving, and your eyes automatically move the opposite way to keep the image steady.

Close to Home

During wildfire smoke season in the Valley, some people say food tastes flat or "off." Much of what we call flavor actually comes from smell, so smoky air and irritated noses can change how food tastes.

Check Your Understanding

1. What two clues help your brain decide that signals belong to the same event?
2. In the ventriloquism effect, which sense wins for location?
3. What is the principle of inverse effectiveness?
4. Which reflex keeps your vision steady when your head moves?

The answers are in the unit you just read.

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Unit 5.6: Sight, Touch, and Body Ownership

Learning Objectives

By the end of this unit, you will be able to:

- Describe the rubber hand illusion and what it shows about body ownership.
- Define proprioception.
- Explain which sense tends to win for timing and which for location.

Can you feel a fake hand? Imagine one of your hands is hidden behind a screen, and a rubber hand sits in front of you. A researcher brushes your hidden hand and the rubber hand at the same time, in the same spots. After a few minutes, many people start to feel as if the rubber hand is their own.

The Rubber Hand Illusion

This is the **rubber hand illusion**, first described by Matthew Botvinick and Jonathan Cohen (1998). Afterward, when people were asked to point to their hidden hand, they pointed closer to the rubber hand than where their real hand was. In later studies, when the rubber hand was suddenly threatened, people showed a stress response, such as sweaty skin, even though their real hand was safe (Armel & Ramachandran, 2003).

Normally you know where your body parts are through **proprioception**, the sense of your body's position from receptors in your muscles and joints. In the illusion, what you see and feel at the same time overrides that sense. Your feeling that your body is yours depends on your brain blending sight and touch.

In Plain Words

Your brain is like a detective weighing clues. When the brushing you see matches the brushing you feel, the simplest explanation is "that's my hand," even when it isn't.

Which Sense Wins?

Vision doesn't always win. In the **double-flash illusion**, one quick flash of light paired with two quick beeps often looks like two flashes (Shams et al., 2000). Hearing is better at timing, so it wins for "when," while vision usually wins for "where." Your brain tends to trust whichever sense is most reliable for the job.

Why It Matters

- People using prosthetic limbs may feel the device is more a part of their body when what they see and feel match.
- Virtual reality works by giving your eyes, ears, and body matching signals.
- Motion sickness can happen when senses disagree, like when your inner ear feels a car moving but your eyes are fixed on a phone.

Check Your Understanding

1. Who first described the rubber hand illusion, and in what year?
2. What is proprioception?
3. In the double-flash illusion, which sense changes what you see?

> *The answers are in the unit you just read.*

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Unit 5.7: Seeing Speech

Learning Objectives

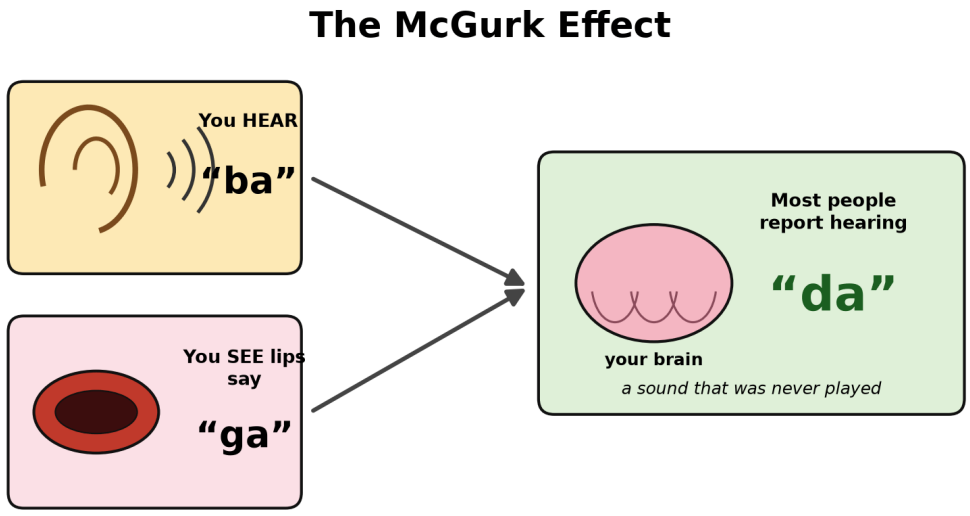
By the end of this unit, you will be able to:

- Describe the McGurk effect.
- Explain how seeing a speaker's face helps people understand speech.

Ever turned a video's volume down and still followed what someone said by watching their lips? Your brain blends what you see and hear to understand speech. This is called **audiovisual speech**, and it's especially helpful in loud places or on a choppy video call.

The McGurk Effect

Researchers recorded someone saying "ga," then dubbed in the sound "ba." What did people hear? Not "ga" or "ba." In the original study, 98% of adults reported "da," a sound that wasn't there (McGurk & MacDonald, 1976). This is the **McGurk effect**, named after psychologist Harry McGurk. It shows how strongly your brain merges sight and sound, even when they don't match. The diagram below shows how it works.



Based on McGurk and MacDonald (1976).

> **Image description:** A three-part diagram of the McGurk effect. At the top left, an ear icon shows the sound being played: "ba." Below it, a mouth icon shows the lip movements being watched: "ga." Arrows from both lead to a brain icon on the right, labeled with what most people report hearing: "da," a sound that was never played.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Seeing a Voice

Faces carry clues about voices. In one study, people who had watched silent videos of a person talking later understood that person's voice better in noise, even though they had never heard it (Rosenblum et al., 2007). People can also match a voice to a silent video of the speaker's face better than chance, and the match works in both directions (Kamachi et al., 2003).

From a Peer

“I work the front counter at a taco shop after class, and orders get shouted over the grill. I didn’t realize how much I read lips until people wore masks and I kept getting orders wrong.”

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Unit 5.8: Module Wrap-Up

You made it through Module 5. Before you move on to hearing, taste, smell, touch, pain, and balance, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Your brain, not just your eyes, builds what you see, so what you see isn't always what's really there, because your brain fills in blanks and filters out distractions (5.1).
- In the retina, rods work best in dim light and cones handle color and fine detail, and each eye has a blind spot where the optic nerve leaves, which your brain fills in (5.2).
- Your visual system cares most about contrast, lateral inhibition makes edges stand out even more, and full dark adaptation can take 20 to 30 minutes after the lights go off (5.2).
- Visual signals travel from the eye through a relay station in the thalamus to the primary visual cortex at the back of the brain, then split into a ventral "what" stream and a dorsal "where/how" stream (5.3).
- Your brain compares the slightly different views from your two eyes, called binocular disparity, to judge depth (5.3).
- Sensation is your sense organs detecting energy, perception is your brain organizing and interpreting those signals, and synesthesia is a reminder that perception happens in the brain (5.4).
- Your brain decides which signals belong together by checking whether they come from the same place at the same time, which is why a ventriloquist's voice seems to come from the puppet (5.5).
- Some neurons fire much more to a sight and a sound together than you'd expect from each alone, called the superadditive effect, and combining senses helps most when each sense alone is weak, called the principle of inverse effectiveness (5.5).
- The rubber hand illusion shows that your feeling that your body is yours depends on your brain blending sight and touch, and your brain tends to trust whichever sense is most reliable for the job (5.6).
- In the McGurk effect, seeing a face say "ga" while hearing "ba" makes most people hear "da," which shows how strongly your brain merges sight and sound to understand speech (5.7).

Why This Module Matters

You use these ideas every day without thinking about them. Valley drivers know how tule fog washes out the edges of cars and lane lines, leaving your visual system less contrast to work with, which is why slowing down and using low-beam headlights helps. At a loud counter or in a noisy cafeteria, you understand people better when you can see their lips. And some of this research happens close to home, at Fresno State.

Knowing that your brain builds what you see and hear can help you stay safer on the road, and be patient with yourself and others when the senses get fooled.

Module 5 ideas in everyday life

Idea	Where you met it	Where you might see it
Contrast	5.2	Driving in tule fog, when lane lines and other cars are hard to see
Dark adaptation	5.2	Bumping into furniture right after you turn off the lights
Depth perception	5.3	Learning to judge distance with new gear, like a welder using shadows and reflections through a dark lens
Inverse effectiveness	5.5	Watching a friend's lips to follow what they say in a loud cafeteria
Senses that disagree	5.6	Feeling carsick when your eyes are on your phone but your inner ear feels the car moving
Audiovisual speech	5.7	Getting orders wrong at a noisy counter when people wore masks

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Think of a time your eyes or ears fooled you, like seeing something that wasn't there or mishearing a word. What do you think your brain was filling in?
2. When is it hardest for you to see or hear clearly: night driving, fog, a noisy room, or a video call? What do you already do to help, and what might you try now?
3. Do you watch people's faces and lips more than you realized? Think about a place in your life where that helps you most.
4. Two people can have the same sensation but different perceptions. When have you and someone else experienced the same moment very differently?

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Unit 5.9: References

About This Module

This module was adapted and rewritten by Michael Miguel from his earlier Vision and Perception module, which drew on the Noba modules *Vision* by Simona Buetti and Alejandro Lleras and *Multi-Modal Perception* by Lorin Lachs, licensed CC BY-NC-SA 4.0. Changes: condensed and rewritten in plain language for Coalinga College campus and Rising Scholars students, with Central Valley examples, review questions, corrected facts, and new diagrams. Terms are defined in the book Glossary.

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MODULE 6: OTHER SENSES: HEARING, TASTE, SMELL, TOUCH, AND BALANCE



> **Image description:** An artistic poster titled “Other Sensory Systems.” A glowing brain inside a person’s head is connected by threads of light to five circles: an ear with sound waves (hearing), an eye (sight), a person smelling lavender (smell), a fingertip touching a leaf (touch), and berries and an orange slice (taste). This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

You just saw how much work goes into seeing. Your other senses are just as busy. Right now, your ears are sorting voices from background noise, your nose and tongue are ready to judge your next snack, your skin is reporting the feel of your chair, and your inner ear is keeping you upright.

In this module, you’ll follow each of these senses from the receptor to the brain. You’ll also see why pain isn’t just a measure of injury, why your brain can turn pain down when it needs to, and how a few tiny crystals in your inner ear help you keep your balance.

Learning Objectives

By the end of this module, you will be able to:

- Describe the main features of sound (loudness, pitch, and timbre) and how the ear turns sound into nerve signals.
- Explain how the brain locates sounds and picks out one voice in a noisy room.
- Describe how taste and smell work, and explain which food likes and dislikes are built in and which are learned.
- Identify the main skin receptors and compare fast and slow pain signals.
- Explain how the brain can turn pain up or down, including the gate control theory.
- Describe chronic pain and explain why context and meaning change how pain feels.
- Describe how the vestibular system senses head movement and gravity, and explain motion sickness.

Unit 6.1: Introduction to Hearing

Unit 6.2: Loudness, Pitch, and Timbre

Unit 6.3: How the Ear Works

Unit 6.4: Hearing in a Noisy World
Unit 6.5: Introduction to Taste and Smell
Unit 6.6: How Taste and Smell Work
Unit 6.7: Born to Like Sweet: Built-In and Learned Tastes
Unit 6.8: Introduction to Touch and Pain
Unit 6.9: How Touch Works
Unit 6.10: How the Brain Turns Pain Up or Down
Unit 6.11: When Pain Becomes Chronic
Unit 6.12: Balance: The Vestibular System
Unit 6.13: Module Wrap-Up
Unit 6.14: References

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Unit 6.1: Introduction to Hearing

Learning Objectives

By the end of this unit, you will be able to:

- Describe sound as changes in air pressure.
- Outline the jobs of the outer, middle, and inner ear.

Think about the last time a song gave you chills, or you knew who was calling just from one word. Hearing connects you to people in a way few other senses do. A saying often credited to Helen Keller puts it this way: blindness cuts us off from things, but deafness cuts us off from people.

Sound is tiny, fast changes in air pressure. A voice, a guitar, or a truck engine pushes on the air, and those pressure waves travel to your ears. There, they make your eardrums vibrate, and your ears turn the vibrations into nerve signals that your brain can understand. The infographic below follows sound from a speaker to the brain.



> **Image description:** An infographic titled “How We Hear: From Sound Waves to Meaning.” Sound waves travel from a speaker into a young man’s ear, shown in a cut-away view, and a nerve carries signals to a glowing brain. Six numbered panels read: sound is created; sound enters the ear canal; the eardrum vibrates; the tiny bones of the middle ear amplify the vibrations and pass them to the inner ear; hair cells in the cochlea turn the vibrations into nerve signals; and the brain interprets the sound.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

In the next few units, you’ll follow sound through the outer ear, which gathers it, the middle ear, which boosts it, and the inner ear, which turns it into nerve signals. You’ll also see how your brain figures out what you’re hearing and where it’s coming from.

From a Peer

“I never thought about hearing until I started losing some of it in one ear. Now I notice how hard I work to follow a conversation in a loud room.”

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Unit 6.2: Loudness, Pitch, and Timbre

Learning Objectives

By the end of this unit, you will be able to:

- Explain how loudness is measured in decibels.
- Relate pitch to the frequency of sound waves.
- Define timbre and give an example.

Sound is physical, but what you *hear* is your brain's interpretation. Psychologists describe that experience with three features: loudness, pitch, and timbre.

Loudness

Loudness is how strong a sound seems. It depends mostly on the size of the pressure changes, measured in **decibels** (dB). The scale climbs quickly: every 10 dB increase means 10 times more sound energy, and it sounds roughly twice as loud. Loudness also depends on pitch. Your ears are most sensitive to sounds in the middle of the range, where most speech falls. The artistic image below shows a concertgoer covering one ear beside a large loudspeaker.

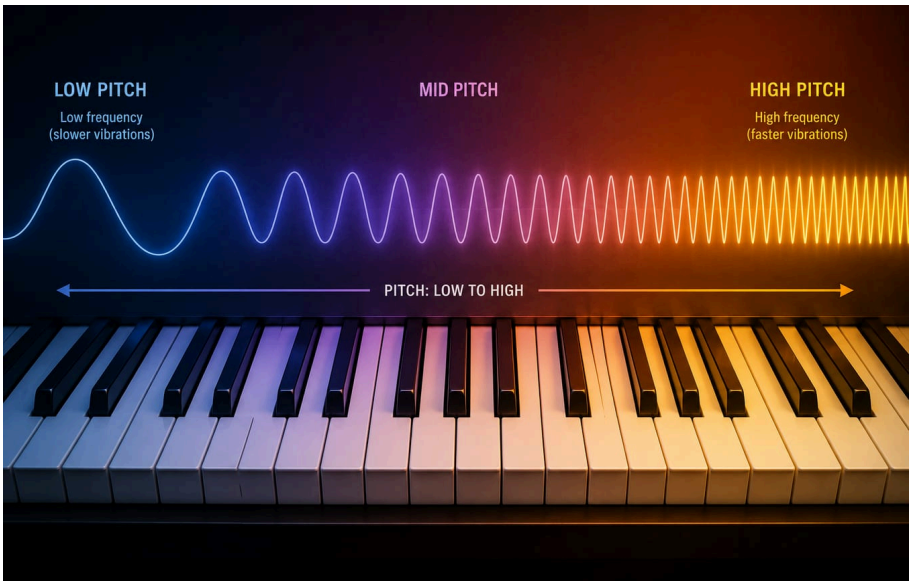


> **Image description:** At a crowded concert, a young man presses a hand over his ear. Next to him, a large loudspeaker sends out rings of sound toward the stage lights and crowd. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Pitch

Pitch is how high or low a sound seems. It depends on **frequency**, the number of pressure waves per second, measured in hertz (Hz). Faster waves sound higher. Young people can hear from about 20 Hz to 20,000 Hz, and the top of that range drops with age and noise exposure. Pitch carries the melody in music and the emotion in a voice. Say "really?" and then "really." and you'll hear pitch change the meaning. The image below shows how pitch rises as sound waves come faster.

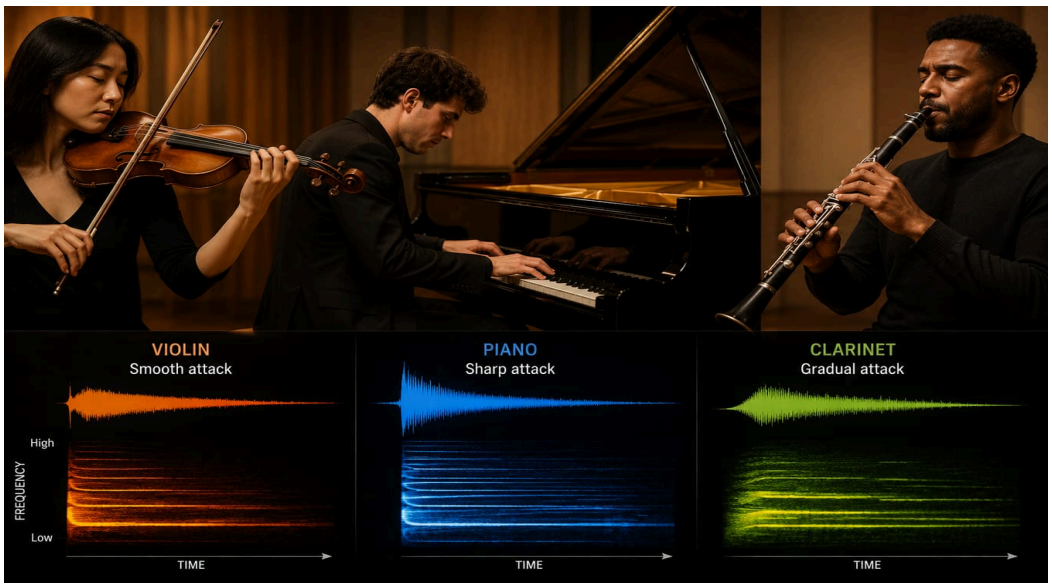


> **Image description:** A glowing wave stretches across a piano keyboard. On the left, labeled low pitch and low frequency (slower vibrations), the waves are far apart. On the right, labeled high pitch and high frequency (faster vibrations), they are packed close together. An arrow reads Pitch: Low to High. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Timbre

Timbre (pronounced “TAM-ber”) is what makes two sounds with the same loudness and pitch sound different, like a guitar and a trumpet playing the same note. It comes from the mix of frequencies in a sound and how the sound starts and fades. A piano note starts sharply when the hammer strikes; a violin note can swell in slowly. Timbre is also how you recognize a friend’s voice. The image below shows how three instruments make different sound patterns.



> **Image description:** Three musicians play a violin, a piano, and a clarinet. Below each is a stylized picture of its sound over time. The violin has a smooth start, the piano a sharp start that fades, and the clarinet a gradual start. Each instrument shows a different set of stripes from low to high frequency, which is why each one has its own timbre. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

In Plain Words

Loudness is the volume knob, pitch is which key on the piano, and timbre is which instrument is playing.

Check Your Understanding

1. What unit measures loudness?
2. What physical feature of sound sets its pitch?
3. About what range of frequencies can young people hear?
4. What makes a guitar and a trumpet sound different on the same note?

The answers are in the unit you just read.

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Unit 6.3: How the Ear Works

Learning Objectives

By the end of this unit, you will be able to:

- Trace sound from the pinna and eardrum to the cochlea.
- Explain how hair cells on the basilar membrane turn vibrations into nerve signals and how tonotopic organization codes pitch.
- Explain how the brain uses differences between the two ears to locate sounds.

Your ear has three main parts. Each one changes sound into a form the next part can use.

The Outer Ear

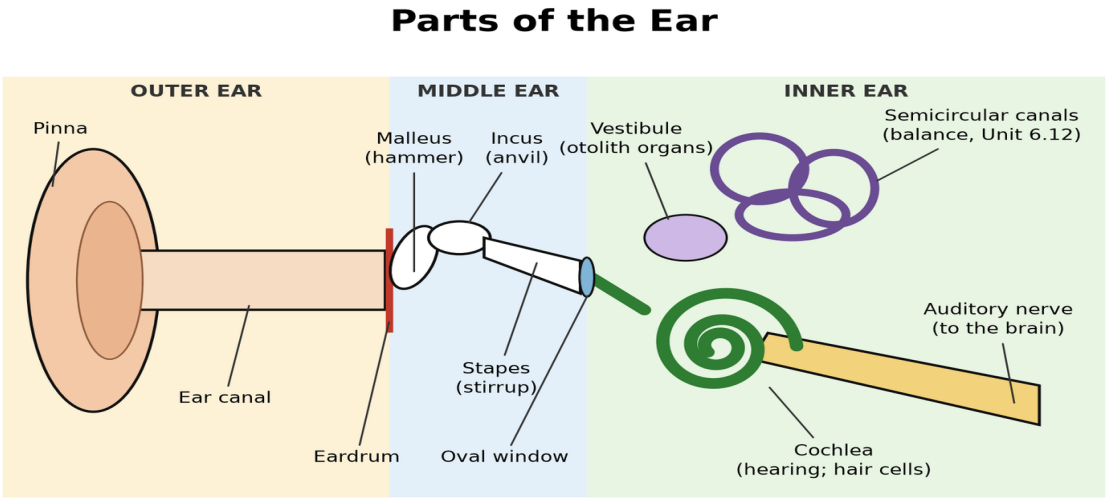
The outer ear includes the **pinna** (the part you can see), the ear canal, and the **eardrum**, a thin membrane that vibrates when sound hits it. The pinna's folds do more than look interesting. They change sounds slightly depending on where the sounds come from, which helps you tell front from back and up from down.

The Middle Ear

Behind the eardrum is an air-filled space with the three smallest bones in your body: the malleus (hammer), incus (anvil), and stapes (stirrup). They pass vibrations from the eardrum to the oval window of the inner ear and boost them along the way. That boost is needed because the inner ear is filled with fluid, which is much harder to move than air.

The Inner Ear

The **cochlea** is a fluid-filled, snail-shaped tube. Running along it is the **basilar membrane**, which holds rows of **hair cells**. When vibrations move the membrane, tiny hair-like tips on these cells bend, and the cells send signals along the **auditory nerve**. Different spots respond to different pitches: high sounds near the base of the cochlea, low sounds near the tip. This orderly map of pitch, called **tonotopic organization**, continues all the way to the **auditory cortex** in the temporal lobe.



Simplified diagram, not drawn to scale. Sound travels left to right.

> **Image description:** A diagram of the ear in three sections. The outer ear has the pinna and the ear canal, which ends at the eardrum. The middle ear holds three tiny bones, the malleus (hammer), incus (anvil), and stapes (stirrup), which pass vibrations to the oval window of the cochlea. The inner ear has the snail-shaped cochlea, where hair cells turn vibrations into nerve signals that travel along the auditory nerve to the brain. The balance organs, the semicircular canals and the vestibule (which holds the otolith organs), sit just above the cochlea. The diagram is simplified and not drawn to scale.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Where Is That Sound?

Having two ears helps you locate sounds. A sound on your left reaches your left ear a tiny bit sooner and a bit louder than your right ear, and your brain uses both differences. Your brain also learns your pinnas' effects. When researchers reshaped people's outer ears with molds, the volunteers at first couldn't tell whether sounds came from above or below them. After a few weeks, they had relearned, and when the molds came off, they could still use their own ears right away (Hofman et al., 1998).

Check Your Understanding

1. What are the three tiny bones of the middle ear?
2. Which cells in the cochlea turn vibrations into nerve signals?
3. Where in the cochlea are high-pitched sounds detected?
4. What two differences between your ears help you locate a sound?

The answers are in the unit you just read.

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Unit 6.4: Hearing in a Noisy World

Learning Objectives

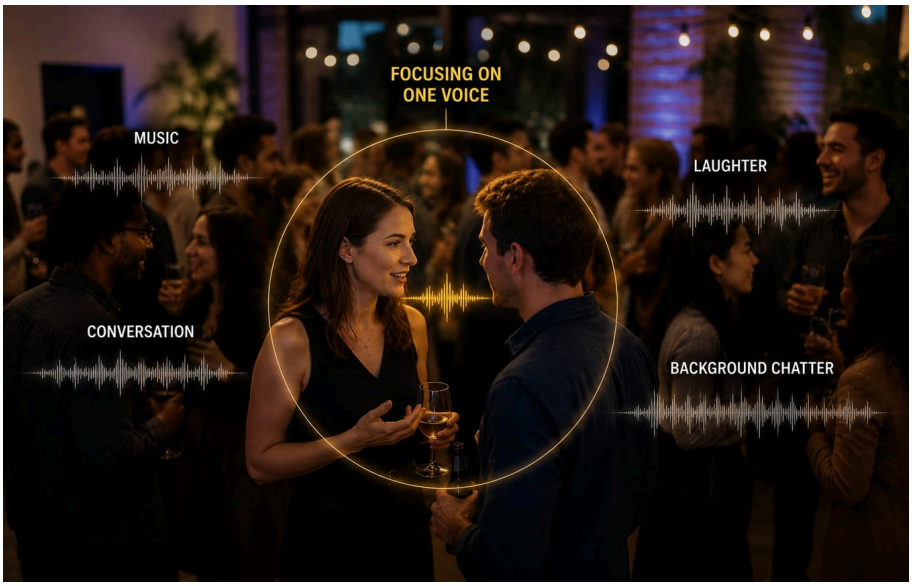
By the end of this unit, you will be able to:

- Define auditory scene analysis and the cocktail party effect.
- Explain why loud noise can cause permanent hearing loss and why hearing protection matters.

At a family party, music is playing, kids are yelling, and three conversations overlap. Yet you can follow your cousin's story. How?

All those sounds arrive at your eardrum mixed into one complicated wave. Your brain has to pull them apart into separate sources, a process called **auditory scene analysis**. It groups sounds that start and stop together, that share a pitch, or that follow the same rhythm, and it treats sounds that don't match as coming from somewhere else.

Being able to tune in to one voice and tune out the rest is called the **cocktail party effect**. Seeing the speaker's lips helps too, as you saw in Module 5. Fatigue, aging, and hearing loss make this harder, which is why people with hearing loss often find noisy restaurants exhausting. Modern hearing aids and cochlear implants use this research to pull speech out of background noise. The image below shows one conversation standing out from the noise of a party.



> **Image description:** At a busy evening party, a circle surrounds two people talking, labeled Focusing on One Voice. Around them, sound waves are labeled music, laughter, conversation, and background chatter. The picture shows how the brain picks out one voice from many sounds. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Close to Home

Tractors, harvesters, packing-house machinery, and oil-field equipment can be loud enough to damage hearing. Health experts recommend hearing protection when noise averages 85 dB or more over a work shift (National Institute for Occupational Safety and Health, 2024). Hair cells destroyed by noise don't grow back, so foam earplugs or earmuffs at work really do protect your hearing for life.

From a Peer

"I drove a tractor every summer growing up and never wore earplugs. Now I have ringing in my ears and can't follow people at a loud restaurant. I make my little brother wear them."

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Unit 6.5: Introduction to Taste and Smell

Learning Objectives

By the end of this unit, you will be able to:

- Describe the omnivore's dilemma.
- Distinguish taste, smell, and flavor, and explain why food tastes flat with a stuffy nose.

Humans are **omnivores**: we can eat almost anything, from fruit to meat to roots. That flexibility helped our ancestors survive, but it creates a problem. How do you choose foods that nourish you and avoid ones that could poison you? This is called the **omnivore's dilemma**.

Taste and smell work together to solve it. **Taste** (gustation) gives quick, built-in signals: sweet suggests energy, salty suggests needed minerals, umami (savory) suggests protein, sour can warn of spoiled food, and bitter can warn of poison. **Smell** (olfaction) adds the rich detail of **flavor**, and its likes and dislikes are mostly learned from experience.

Most of what you call the "taste" of a food is really smell. Hold your nose while eating a jelly bean, and you can tell it's sweet but not what flavor it is. That's why food tastes so flat when you have a stuffy nose, and why a sudden loss of taste or smell, as many people had with COVID-19, is worth mentioning to a health care provider. The infographic below shows the omnivore's dilemma.



> **Image description:** An infographic titled "The Omnivore's Dilemma: Choosing foods that nourish and avoiding those that harm." A woman looks thoughtfully at salad, salmon, berries, nuts, bread, and yogurt. A thought bubble lists what taste tells us: sweet means energy-rich carbohydrates, salty means essential minerals, sour warns of unripe or spoiled food, bitter may mean toxins, and umami signals protein. It adds that smell provides rich information about flavor, safety, and preference. A second bubble, "Avoid potential harm," shows wild mushrooms, a moldy apple, and a poison bottle.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

From a Peer

"When I had COVID, my mom's cooking tasted like nothing. That's when I realized how much of eating is really smell."

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Unit 6.6: How Taste and Smell Work

Learning Objectives

By the end of this unit, you will be able to:

- Describe how olfactory receptor cells, glomeruli, and the olfactory bulb identify smells.
- Describe how papillae and taste buds detect the basic tastes.
- Explain why the “tongue map” is a myth.

Taste and smell are **chemical senses**. Instead of light or sound, they detect molecules.

Smell

High in your nose, millions of **olfactory receptor cells** detect airborne molecules called odorants. Humans have about 350 kinds of olfactory receptors, and each kind responds to certain features of a molecule. Most smells, like coffee or tortillas on the comal, are mixtures of many chemicals, so each smell activates its own pattern of receptors, like a fingerprint.

Receptors of the same kind send their signals to the same small clusters, called **glomeruli**, in the **olfactory bulb** at the base of the brain. From there, smell signals reach areas involved in emotion and memory, which may be why a smell can bring back a memory so quickly.

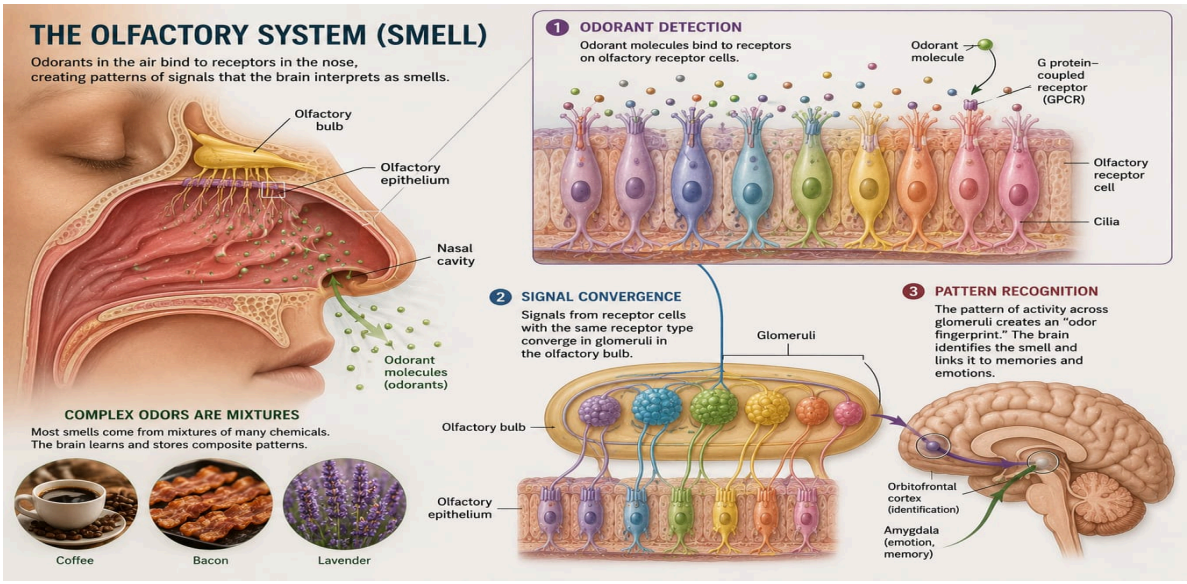


Image description: An infographic titled “The Olfactory System (Smell).” A cut-away of the nose shows odor molecules rising to the olfactory epithelium, just below the olfactory bulb. Three numbered panels explain: (1) odor molecules bind to receptors on olfactory receptor cells; (2) signals from cells with the same receptor type come together in glomeruli in the olfactory bulb; and (3) the pattern of activity creates an odor fingerprint that the brain identifies and links to memories and emotions, through areas such as the orbitofrontal cortex and amygdala. A corner panel notes that most smells, like coffee, bacon, and lavender, are mixtures of many chemicals.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Taste

Your tongue's bumps are called **papillae**. Many of them hold **taste buds**, clusters of taste receptor cells. Taste buds detect five basic tastes: sweet, salty, sour, bitter, and umami. You may have seen a "tongue map" showing sweet only at the tip and bitter only at the back. That map is a myth: every area with taste buds can detect all five tastes.

Sweet, umami, and bitter tastes are detected by receptor proteins on the taste cells. Humans have about 25 kinds of bitter receptors, which makes sense, since there are many different poisons to avoid. Salty and sour are detected more directly, through channels that let charged particles into taste cells.

Artificial sweeteners activate sweet receptors without the calories. You'd think that would help with weight loss, but the evidence is mixed. In one rat study, animals given saccharin instead of sugar actually gained more weight, possibly because the sweet taste no longer predicted calories (Swithers & Davidson, 2008). Rats aren't people, and human studies are still sorting this out.

Check Your Understanding

1. About how many kinds of olfactory receptors do humans have?
2. Where do smell signals go first in the brain?
3. What are the five basic tastes?
4. True or false: you taste sweet only on the tip of your tongue.

The answers are in the unit you just read.

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Unit 6.7: Born to Like Sweet: Built-In and Learned Tastes

Learning Objectives

By the end of this unit, you will be able to:

- Distinguish built-in taste reactions from learned ones.
- Compare orthonasal and retronasal olfaction.
- Explain how a conditioned taste aversion forms.

Some food reactions are with you from birth. Others you learn. Both help solve the omnivore's dilemma.

Built-In Reactions

Newborns love sweet, like the taste of breast milk, and make a disgusted face at bitter. A liking for salt shows up a few months after birth (Beauchamp et al., 1986). Sour is usually disliked, though many kids learn to love sour candy. These built-in reactions are part of why sweet, salty, sour, bitter, and umami count as basic tastes.

Learned Smells and Flavors

Smell reaches you in two ways. Sniffing through your nostrils is **orthonasal olfaction**. When you chew and swallow, odors also travel from the back of your mouth up into your nose. This is **retronasal olfaction**, and your brain blends it with taste to create flavor.

Flavors are easily linked to how you felt afterward. If a food is followed by nausea, you may avoid it for years, a **conditioned taste aversion**. In one survey of food aversions, people said that in 29% of cases even the smell of the food had become unpleasant (Bartoshuk & Wolfe, 1990). Liking a flavor through good experiences is slower, but it happens: think of foods from family meals and celebrations that you grew to love.

What about human **pheromones**, smells that supposedly trigger attraction? Despite sprays sold online, careful research hasn't found good evidence that they work in humans (Doty, 2010).

Close to Home

Chile's "heat" isn't a taste at all. Capsaicin activates heat-pain receptors in your mouth, the same ones that respond to a hot stove. Many Valley kids learn to love salsa and Takis anyway, a great example of a learned preference.

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Unit 6.8: Introduction to Touch and Pain

Learning Objectives

By the end of this unit, you will be able to:

- Explain why touch and pain help protect us, using real cases.
- Describe how touch connects us to others and to our own bodies.

Imagine never feeling pain. Sounds great? Think again.

In a large Swedish family, a gene mutation keeps the nerves that carry deep pain from growing normally. One boy, called “Thomas” in research reports, never felt deep pain. After he broke a leg, he kept walking on it, and the bones of his other leg were slowly crushed under the extra weight. Many people in his family have joint damage and frequent fractures (Minde et al., 2004). For them, life without pain is dangerous.

Losing touch is just as hard. After an antibiotic treatment damaged her nerves, a woman known as G.L. lost the sense of touch and the sense of where her body was. She said she felt “disembodied” from the nose down. If she didn’t watch her arms and legs, they could “wander off,” and with her eyes closed she would fall (Olausson et al., 2002).

These cases show that touch and pain do more than inform. They protect you, connect you to other people, and give you a sense of your own body.

From a Peer

“I used to think pain was just the enemy. Now I see it’s also my body’s alarm system, and I want to understand it, not just shut it off.”

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Unit 6.9: How Touch Works

Learning Objectives

By the end of this unit, you will be able to:

- Identify the main kinds of skin receptors: mechanoreceptors, thermoreceptors, and nociceptors.
- Explain why fast and slow pain travel on A-delta fibers and C-fibers.
- Describe the role of C-tactile fibers in comforting touch.

Your skin is your largest organ and your body's main contact with the world. The senses of the skin, along with the sense of body position, make up the **somatosensory system**.

Receptors in the Skin

Skin receptors turn physical energy into nerve signals. **Mechanoreceptors** respond to pressure, vibration, and stretch, so you can feel texture and grip a cup. **Thermoreceptors** respond to warmth and cold. **Nociceptors** respond to things that could damage tissue, like burning heat, crushing pressure, or chemicals released by injured cells, and their signals can lead to pain. Other receptors signal itch.

Touch signals travel up the spinal cord to the **somatosensory cortex** in the parietal lobe, which has a map of the body. Body parts that need fine touch, like the lips and fingertips, get the most space on that map.

Fast Pain, Slow Pain

Step on a tack and you feel two pains: a quick, sharp jab and then a slower, dull ache. They travel on different fibers. Sharp pain is carried by **A-delta fibers**, which are thin but coated with myelin, so they're fast. The ache is carried by **C-fibers**, which are even thinner and have no myelin, so they're slow. The sharp signal tells you where it hurts. The slow signal reaches brain areas for emotion, like the insula, and tells you how bad it feels.

Touch That Comforts

Some C-fibers, called **C-tactile fibers**, respond best to slow, gentle stroking, like a caress, and their activity tracks how pleasant the touch feels (Löken et al., 2009). They may help explain why touch matters for bonding. In Harry Harlow's classic studies, baby monkeys spent most of their time clinging to a soft cloth "mother" rather than a wire one that gave milk (Harlow & Zimmermann, 1959). Children raised in orphanages with little personal attention, including touch, often show delays that improve after they move to caring foster homes (Nelson et al., 2007).

Check Your Understanding

1. What kind of receptor responds to potentially harmful stimuli?
2. Which fibers carry the quick, sharp pain?
3. Which brain area holds a map of touch across the body?
4. What kind of touch do C-tactile fibers respond to best?

The answers are in the unit you just read.

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Unit 6.10: How the Brain Turns Pain Up or Down

Learning Objectives

By the end of this unit, you will be able to:

- Explain how the periaqueductal gray and endorphins can block pain.
- Describe the placebo effect on pain.
- Explain gate control theory.

In 2003, climber Aron Ralston was trapped for five days in a Utah canyon when a boulder pinned his arm. To survive, he broke the bones in his forearm and cut through it with a dull multi-tool. Cutting the main nerve was agonizing, but he described a wave of excitement as he freed himself. He then rappelled down a cliff and hiked miles before rescuers found him (Ralston, 2010). How could he keep going?

Descending Pain Control

Pain isn't a simple readout of injury. When something matters more than avoiding pain, such as escaping danger, the brain can send signals down the spinal cord that block pain messages. A key area is the **periaqueductal gray** (PAG) in the midbrain. Much of this system works through **endorphins**, the body's own opioids.

Rewards can turn pain down too. Rats expecting chocolate candy stayed on a hot plate twice as long as rats expecting ordinary food. When the rats' opioid receptors were blocked with a drug, the effect disappeared (Dum & Herz, 1984). Expecting relief works in people as well. In the **placebo effect**, believing a treatment will help reduces pain, partly through the same opioid system (Eippert et al., 2009). Even looking at a photo of a loved one can reduce pain (Master et al., 2009).

The Pain Gate

When you bump your elbow, why does rubbing it help? The **gate control theory** proposes that the spinal cord has a "gate" for pain signals (Melzack & Wall, 1965). Touch signals from rubbing can partly close the gate, and so can signals coming down from the brain.

In Plain Words

Think of pain signals as people trying to get through a door. Rubbing the sore spot, or your brain deciding something else matters more, partly closes the door, so fewer pain messages get through.

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Unit 6.11: When Pain Becomes Chronic

Learning Objectives

By the end of this unit, you will be able to:

- Define chronic pain, allodynia, and sensitization.
- Explain how meaning, fear, sleep, and support change how much something hurts.
- Describe phantom limb pain and mirror therapy.

Pain is supposed to be a short-term alarm. Sometimes the alarm won't turn off.

When Touch Hurts

After a sunburn, even a soft T-shirt can hurt. Pain from something that normally doesn't hurt is called **allodynia**. After some injuries or illnesses, the nervous system becomes overly reactive, a change called **sensitization**. Neurons may fire more easily or even on their own, so pain spreads, grows, or lasts after the tissue has healed.

Chronic Pain

Chronic pain is pain that lasts three months or more. In 2021, about 1 in 5 U.S. adults had chronic pain (Rikard et al., 2023). It often comes with poor sleep, depression, and anxiety, which in turn make pain worse, a hard cycle to break.

Close to Home

Farm, packing-house, and oil-field work involve heavy lifting, repetition, and long hours, and many Valley workers live with back, knee, or shoulder pain. Physical therapy, safe lifting, and treating pain early can help keep short-term pain from becoming chronic.

Meaning Matters

How much something hurts depends on what it means. In one study, the same moderate heat felt worse when it was the worst possible outcome, and it was even rated pleasant when it meant avoiding something more painful (Leknes et al., 2013). Fear and focusing on pain tend to make it worse. Distraction, good sleep, movement, and support from others tend to help.

The brain can even create pain without input. Many people who lose a limb feel pain in the missing limb, called **phantom limb pain**. In **mirror therapy**, a mirror makes the missing limb appear to move, which helps some people. And when you watch someone you love get hurt, parts of your own pain network, like the insula, become active (Singer et al., 2004).

From a Peer

"When pain medication wasn't an option for me, I learned slow breathing, stretching, and walking every day. The pain didn't vanish, but I got some control back."

Check Your Understanding

1. What is allodynia?

2. How long must pain last to count as chronic?
3. About what share of U.S. adults had chronic pain in 2021?
4. What is phantom limb pain?

The answers are in the unit you just read.

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Unit 6.12: Balance: The Vestibular System

Learning Objectives

By the end of this unit, you will be able to:

- Describe how the semicircular canals and otolith organs sense head movement and tilt.
- Explain the role of head direction cells and the vestibulo-ocular reflex.
- Explain why motion sickness happens.

Spin in a circle and stop. The room seems to keep turning. That dizzy feeling comes from your **vestibular system**, the balance organs in your inner ear, right next to the cochlea. It senses head movement and gravity, and it works with your eyes and your body sense to keep you upright and your vision steady. The infographic below shows the inner-ear balance organs and the senses that work with them.



> **Image description:** An infographic about balance. A blurred photo of a woman spinning reads "Spin, stop, and the world keeps turning. That's your vestibular system in action." A drawing of the inner ear labels the semicircular canals, utricle, saccule, and vestibular nerve. Below, "A Team Effort for Balance" shows vision plus proprioception (the body sense) plus the vestibular system adding up to balance and coordination. A bar at the bottom lists signs of trouble: dizziness, motion sickness, and loss of balance.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

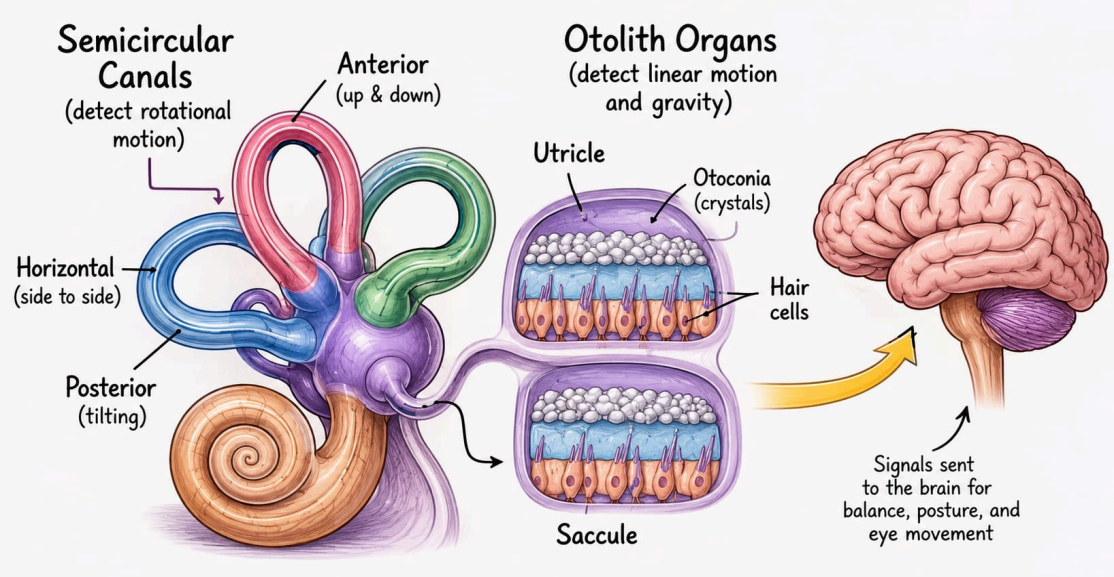
Sensing Turns: The Semicircular Canals

Each inner ear has three fluid-filled loops called **semicircular canals**, set at right angles to each other. Together they sense turning in any direction: nodding yes, shaking no, or tilting your head toward a shoulder. When your head turns, the fluid lags behind and bends hair cells, like the ones used for hearing. After you spin and stop, the fluid keeps moving for a moment, so your brain thinks you're still turning.

Sensing Tilt: The Otolith Organs

Two **otolith organs**, the utricle and saccule, sense tilt and straight-line movement, like speeding up in a car or rising in an

elevator. Their hair cells sit under a jelly layer topped with tiny crystals called **otoconia**. When you tilt your head or speed up, the crystals shift and bend the hair cells. If crystals break loose into a canal, brief spinning dizziness can occur when you roll over in bed, a common, treatable condition called benign paroxysmal positional vertigo (BPPV). The drawing below shows the semicircular canals and the otolith organs.



> **Image description:** A colored drawing of the inner ear's balance organs. Three semicircular canals, which detect turning, are labeled anterior (up and down), horizontal (side to side), and posterior (tilting). Beside them, close-ups of the two otolith organs, the utricle and saccule, which detect straight-line motion and gravity, show a layer of crystals (otoconia) resting above hair cells. An arrow shows signals going to the brain for balance, posture, and eye movement.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Balance at Work

Vestibular signals go to the brainstem and cerebellum, which adjust your posture and eye movements. One result is the **vestibulo-ocular reflex** you tried in Module 5, which keeps your vision steady as your head moves. Vestibular signals also feed your brain's sense of direction. **Head direction cells** fire depending on which way your head faces, like a compass, and they depend on vestibular input (Yoder & Taube, 2014).

Motion Sickness

Motion sickness happens when your senses disagree. Reading in a moving car, your inner ear feels motion while your eyes say you're sitting still. Looking out the window at the horizon helps by bringing your eyes and inner ear back into agreement. Slow, rolling motion, like a boat on the ocean, is especially likely to cause it.

Close to Home

Driving the curves of Highway 198 over the hills from Coalinga? If you get carsick as a passenger, look out at the road ahead instead of at your phone.

From a Peer

"After learning about the vestibular system, I notice how amazing it is that we can move without even thinking about balance. Now when I get dizzy or carsick, I understand what's happening in my body."

Check Your Understanding

1. What do the semicircular canals sense?
2. What are otoconia?
3. Which cells act like a compass for head direction?
4. Why does reading in a moving car cause motion sickness?

The answers are in the unit you just read.

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Unit 6.13: Module Wrap-Up

You made it through Module 6. Before you move on to consciousness, sleep, and attention, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Sound is tiny, fast changes in air pressure, and you hear it as loudness (measured in decibels), pitch (set by frequency), and timbre, which lets you tell a guitar from a trumpet or recognize a friend's voice (6.1, 6.2).
- The outer ear gathers sound, the three tiny bones of the middle ear boost it, and hair cells in the cochlea turn the vibrations into nerve signals, with high pitches sensed near the base and low pitches near the tip (6.3).
- Your brain locates sounds by comparing when and how loudly they reach each ear, and it pulls one voice out of a noisy room through auditory scene analysis, the cocktail party effect (6.3, 6.4).
- Hair cells destroyed by noise don't grow back, so health experts recommend hearing protection when noise averages 85 dB or more over a work shift (6.4).
- Taste gives quick, built-in signals about sweet, salty, sour, bitter, and umami, while smell adds most of what we call flavor, which is why food tastes flat when you have a stuffy nose (6.5, 6.6).
- Some food reactions, like liking sweet and disliking bitter, are present from birth, while others are learned, such as a taste aversion after getting sick or a growing love for spicy salsa (6.7).
- Cases of people who can't feel pain or touch show that these senses protect you, connect you to other people, and give you a sense of your own body (6.8).
- Skin receptors sense pressure, temperature, and possible damage, and pain arrives in two waves: a quick, sharp jab carried by A-delta fibers and a slower ache carried by C-fibers (6.9).
- Pain isn't a simple readout of injury, because the brain can turn it down through endorphins, the placebo effect, and the spinal "gate" described by gate control theory (6.10).
- Chronic pain lasts three months or more, and what pain means to you, along with sleep, movement, and support from others, can change how much it hurts (6.11).
- The vestibular system in your inner ear senses head turns and tilt, and motion sickness happens when your inner ear and your eyes disagree (6.12).

Why This Module Matters

Your senses do more than inform you; they protect you. Tractors, harvesters, packing-house machinery, and oil-field equipment can be loud enough to damage hearing for life, and foam earplugs or earmuffs really do help. Many Valley workers live with back, knee, or shoulder pain from heavy lifting and long hours, and treating pain early can help keep it from becoming chronic. Even everyday moments, like getting carsick on the curves of Highway 198 or learning to love spicy salsa, make more sense once you know what your senses are doing.

Module 6 ideas in everyday life

Idea	Where you met it	Where you might see it
Hearing protection	6.4	Wearing earplugs or earmuffs around tractors, packing-house machinery, or other loud equipment
Smell and flavor	6.5, 6.6	Food tasting flat when you have a stuffy nose
Conditioned taste aversion	6.7	Avoiding a food for years after it made you sick
Gate control theory	6.10	Rubbing your elbow after you bump it
Chronic pain	6.11	Back or knee pain from heavy lifting and long shifts, where physical therapy and safe lifting can help

Idea	Where you met it	Where you might see it
Motion sickness	6.12	Getting carsick as a passenger, and feeling better when you look at the road ahead instead of your phone

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Which sense do you rely on most at work, at home, or in class? How would your day change if it suddenly got weaker?
2. Think of a food you love or can't stand. Do you think that reaction is built in or learned? What experiences might have shaped it?
3. Think of a time when pain felt worse or better because of what was going on around you, like stress, distraction, or someone you trust nearby. What made the difference?
4. What is one small thing you could do this week to protect your hearing, your back, or another sense you depend on?

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Unit 6.14: References

About This Module

This module was adapted and rewritten by Michael Miguel from his earlier Other Sensory Systems and Vestibular System modules, which drew on the Noba modules *Hearing* by Andrew J. Oxenham, *Taste and Smell* by Linda Bartoshuk and Derek Snyder, *Touch and Pain* by Guro E. Løseth, Dan-Mikael Ellingsen, and Siri Leknes, and *The Vestibular System* by Dora Angelaki and J. David Dickman, licensed CC BY-NC-SA 4.0. Changes: two modules combined and condensed, rewritten in plain language for Coalinga College campus and Rising Scholars students, with Central Valley examples, review questions, corrected facts, and new diagrams. Terms are defined in the book Glossary.

References

Web addresses are printed for reference only; you don't need them for this course.

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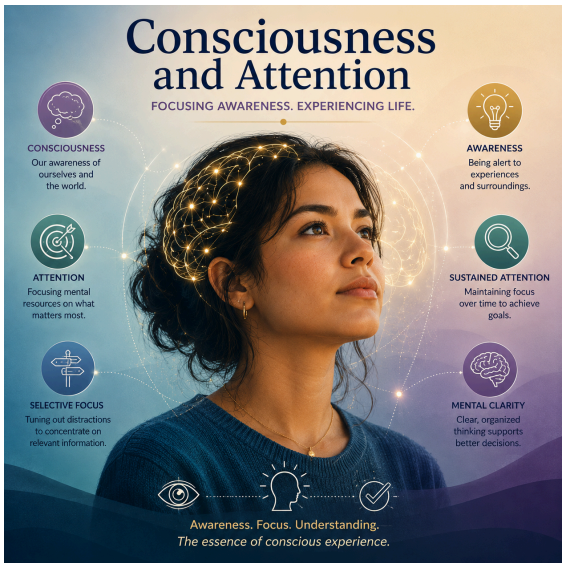
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MODULE 7: CONSCIOUSNESS, SLEEP, AND ATTENTION



> **Image description:** An artistic poster titled "Consciousness and Attention: Focusing awareness. Experiencing life." A young woman looks upward with a glowing network of light over her brain. Icons around her are labeled consciousness (our awareness of ourselves and the world), attention (focusing mental resources on what matters most), selective focus (tuning out distractions), awareness, sustained attention (maintaining focus over time), and mental clarity. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Right now you are aware of these words, maybe of a sound in the room, maybe of being a little tired. A few hours from now you'll be asleep, and that awareness will fade and return in cycles all night long. Where does awareness come from, and why can you notice only a small part of the world at once?

In this module, you'll look at levels of awareness, from automatic processing you never notice to focused, mindful attention. You'll learn how your brain's clock times sleep, what happens in each stage of sleep, and why sleep matters so much. Then you'll see how the brain creates conscious vision and how attention selects what reaches awareness, and why multitasking so often fails.

Learning Objectives

By the end of this module, you will be able to:

- Define consciousness and explain how scientists study it.
- Distinguish low and high levels of awareness, and give examples of priming and automatic processing.
- Explain how the circadian rhythm is controlled, and describe the stages of sleep and common sleep disorders.
- Describe what hypnosis can and cannot do.
- Explain what blindsight and inattentional blindness show about conscious vision.
- Compare early-selection and attenuation models of selective attention.
- Explain why multitasking usually hurts performance, especially while driving.

Unit 7.1: Introduction to Consciousness

Unit 7.2: Levels of Awareness

Unit 7.3: Sleep and Biological Rhythms

Unit 7.4: Hypnosis and Other States
Unit 7.5: Conscious Vision
Unit 7.6: Introduction to Attention
Unit 7.7: Selective Attention
Unit 7.8: Divided Attention and Multitasking
Unit 7.9: Module Wrap-Up
Unit 7.10: References

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Unit 7.1: Introduction to Consciousness

Learning Objectives

By the end of this unit, you will be able to:

- Define consciousness.
- Explain why consciousness is hard to study and how researchers combine self-reports with outside measures.

Imagine what it means to be you right now. You're reading these words, sitting somewhere specific, and you can feel your breathing, your thoughts, maybe an emotion. No one else can experience exactly what it feels like to be you. That private awareness is what we call **consciousness**: your awareness of yourself and your surroundings.

Consciousness feels like one continuous stream of sights, sounds, memories, and thoughts. But studying it is hard, because only you can observe your own experience. Scientists handle this by combining two kinds of evidence: what people report experiencing (subjective reports) and what can be measured from the outside (objective measures), such as brain activity, reaction times, and eye movements. When the two line up, researchers can ask what the brain is doing at the moment something becomes conscious.

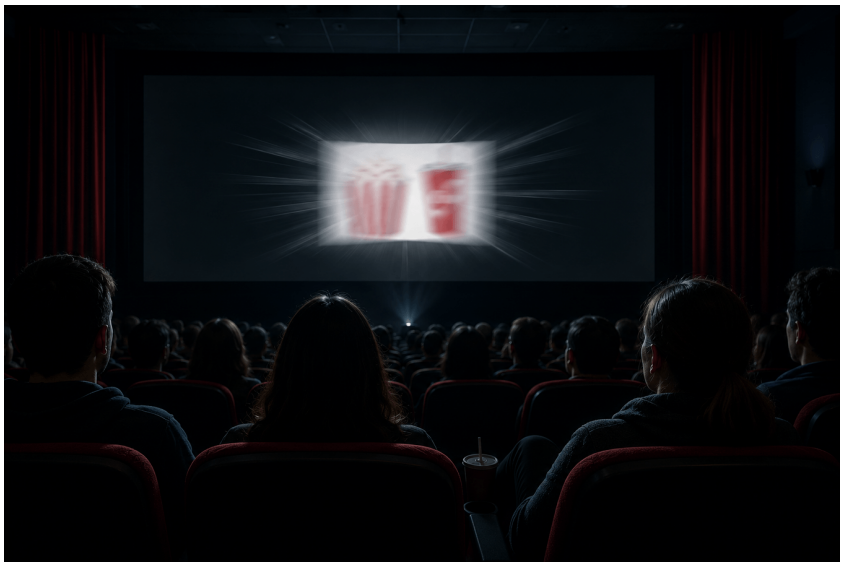
The word "consciousness" can also mean a state, such as being wide awake, drowsy, asleep, or hypnotized. This module covers both: how awareness works, and how it changes across the day and night.

From a Peer

"I always thought I was either paying attention or not. Learning that there are levels in between made a lot of my bad study days make sense."

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Unit 7.2: Levels of Awareness



> **Image description:** A dark movie theater seen from the back rows. On the screen, a blurred flash shows a box of popcorn and a soda cup, as if shown for only an instant. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Learning Objectives

By the end of this unit, you will be able to:

- Define priming and explain why some famous priming findings did not replicate.
- Describe what the Implicit Association Test (IAT) can and can't tell you.
- Describe how mindfulness can reduce stress.

In 1957, a market researcher claimed that flashing "Eat Popcorn" and "Drink Coca-Cola" on a movie screen, too fast to see, raised popcorn sales by almost 58% and Coca-Cola sales by 18%. He later admitted he had made up the data (Pratkanis, 1992). Still, the idea that hidden messages control us stuck. What does science say about awareness below the surface?

Low Awareness

Your brain processes far more than you notice. At a noisy party you tune out most of the chatter, but if someone says your name, you notice right away. Your body can react even when you don't consciously see something. People afraid of snakes started sweating when snake pictures were flashed too quickly to be seen (Öhman & Soares, 1994).

Earlier experiences can also shape how you respond, a process called **priming**. For example, people recognize the word "nurse" faster right after seeing "doctor" (Meyer & Schvaneveldt, 1971). Some famous priming studies have not held up, though. In one, people who unscrambled words about old age seemed to walk more slowly afterward (Bargh et al., 1996), but a careful repeat of that study did not find the effect (Doyen et al., 2012).

The **Implicit Association Test (IAT)** measures how quickly people pair concepts, such as faces and the words "good" or "bad" (Greenwald et al., 1998). Faster pairings suggest stronger automatic associations. The IAT is useful for research, but its scores predict an individual's behavior only weakly (Oswald et al., 2013), so it shouldn't be used to label a person as biased.

High Awareness



> **Image description:** An artistic image titled “High Awareness: Fully attentive. Fully present.” A woman rests her chin on her hand by a sunny window, with a glowing brain drawn inside her head. Icons on the left labeled sights, sounds, and sensations lead to her eyes. Icons on the right read clear thoughts, focused attention, better decisions, and greater awareness. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

At the other end is **high awareness**: deliberately noticing your own thoughts, feelings, and actions. It takes effort, but it lets you catch a snap judgment about someone, pause before reacting in anger, or bring your focus back when your mind wanders. **Mindfulness**, paying calm attention to the present moment without judging it, is one way to practice. Mindfulness training reliably reduces stress in healthy adults (Khoury et al., 2015).

From a Peer

“Last semester I thought a classmate was ignoring me. It turned out his mom was in the hospital. Now I remind myself that I only see part of someone’s story.”

Check Your Understanding

1. What is priming?
2. Why shouldn’t one IAT score be used to label a person?
3. What is mindfulness?

The answers are in the unit you just read.

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Unit 7.3: Sleep and Biological Rhythms

Learning Objectives

By the end of this unit, you will be able to:

- Explain how the suprachiasmatic nucleus (SCN), light, and melatonin set the circadian rhythm.
- Describe the stages of NREM and REM sleep.
- Identify common sleep disorders, such as insomnia, sleep apnea, and narcolepsy.

You spend about a third of your life asleep. Sleep is not just “off.” It is an active state with its own timing, stages, and jobs.

Your Body Clock

Many body functions, including sleepiness, body temperature, and hormone levels, rise and fall on a roughly 24-hour cycle called a **circadian rhythm**. The master clock is the **suprachiasmatic nucleus (SCN)**, a tiny cluster of neurons in the hypothalamus. Light reaching the eyes resets the SCN each day. As evening falls, the SCN signals the **pineal gland** to release **melatonin**, a hormone that helps you feel sleepy. Bright screens at night and travel across time zones can throw this clock off, as in jet lag.

What keeps you awake? In the brainstem, a cluster of neurons called the reticular formation sends signals up through the thalamus to the cortex. This circuit, the ascending reticular activating system, is one of the main systems for staying alert. Groups of neurons in the brainstem and hypothalamus also keep you awake by releasing norepinephrine, serotonin, acetylcholine, and histamine. Other hypothalamus neurons make orexin (hypocretin), which helps you stay awake for long stretches. A sleep-promoting area of the hypothalamus and these wake systems switch each other off (Kirby et al., 2024; National Institute of Neurological Disorders and Stroke, n.d.).

Close to Home

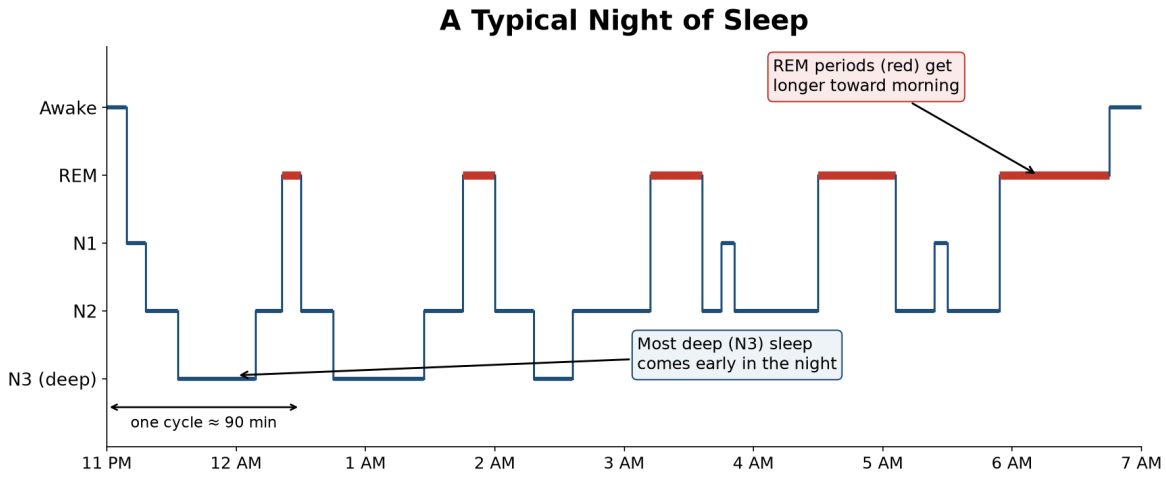
Night shifts, early packing-house start times, and 105° summer nights all fight your body clock. Keeping the same sleep times even on days off, getting bright light when your “day” begins, and making your bedroom dark and as cool as possible can help.

Stages of Sleep

Sleep researchers record brain waves with an electroencephalogram (EEG). Sleep has two main types: non-rapid eye movement (**NREM**) sleep and rapid eye movement (**REM**) sleep.

- **N1:** drifting off; you may feel a sudden jerk or a sense of falling.
- **N2:** light sleep with bursts of activity called sleep spindles, which are linked to memory. It makes up about half of the night.
- **N3:** deep, slow-wave sleep, with large, slow delta waves. It is hardest to wake from.
- **REM:** brain activity looks almost awake, the eyes dart, and most vivid dreams happen. Your muscles are temporarily paralyzed, so you don’t act out your dreams.

You cycle through these stages about every 90 minutes. Deep N3 sleep comes mostly early in the night, and REM periods get longer toward morning. The graph below shows these cycles across one night.



Typical pattern for a young adult; real nights vary.

> **Image description:** A graph of a typical night's sleep, called a hypnogram, from 11 PM to 7 AM. The vertical axis lists awake, REM, N1, N2, and N3 (deep sleep). The line drops from awake through N1 and N2 into N3, rises back to N2, and enters a short REM period, completing a cycle of about 90 minutes. About five cycles follow. N3 deep sleep appears mostly in the first half of the night, while REM periods, shown in red, get longer toward morning. The pattern is typical; real nights vary.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Why Sleep Matters

Sleep helps store memories, clear the mind for learning, and regulate mood and health. Adults need at least 7 hours a night (Watson et al., 2015), but about 1 in 3 U.S. adults get less (Liu et al., 2016). Too little sleep slows reaction time and worsens judgment and mood.

Common **sleep disorders** include **insomnia** (trouble falling or staying asleep), **sleep apnea** (breathing repeatedly stops during sleep, often with loud snoring), and **narcolepsy** (sudden sleep attacks, linked to the loss of neurons that make the wake-promoting chemical orexin; Thannickal et al., 2000). All are treatable, so they are worth raising with a health care provider.

In Plain Words

Your SCN is a clock, light sets it, and melatonin is its "time for bed" signal.

From a Peer

"Where I live now, the lights and noise never fully stop. Earplugs, something over my eyes, and the same bedtime every night help me more than anything."

Check Your Understanding

1. Where is the brain's master clock?
2. Which hormone rises in the evening and promotes sleep?
3. In which stage do most vivid dreams happen?
4. How many hours of sleep do adults need?

The answers are in the unit you just read.

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Unit 7.4: Hypnosis and Other States

Learning Objectives

By the end of this unit, you will be able to:

- Describe what hypnosis is and is not.
- Give examples of trance states and everyday states like daydreaming.

Consciousness isn't an on–off switch. Across a day you move from focused alertness to daydreaming to drowsiness. Some states, like hypnosis and trance, are less common but tell us a lot about attention and expectation.

Hypnosis

Stage shows make **hypnosis** look like mind control. Science describes it more simply: a state of focused, absorbed attention in which people respond more readily to suggestions. People differ in how easily they can be hypnotized, and expectations matter a lot. Hypnosis does not make people act against their values, and it does not reliably uncover hidden memories. In one study, hypnotized people recalled more true details but also more false ones, and they were confident in both (Dywan & Bowers, 1983).

Hypnosis does have real uses. When combined with other treatment, it reduces pain for many people, including during medical procedures (Montgomery et al., 2000). Evidence that it helps people quit smoking or other addictions is mixed.

Trance and Daydreaming

Trance states, often part of religious rituals or ceremonies around the world, also involve deep absorption and a changed sense of control. Most researchers see hypnosis and trance as shifts within ordinary consciousness, shaped by attention, imagination, expectation, and culture, rather than as entirely separate states. Everyday versions are common: "highway hypnosis," when you arrive somewhere with little memory of the drive, and the absorbed state of a good daydream.

Drugs can change consciousness too. They are covered in Module 13, Psychopharmacology.

From a Peer

"I thought hypnosis was a magic trick. Learning it's more like deep focus made it less scary and more interesting."

Check Your Understanding

1. What is hypnosis, in scientific terms?
2. What is one thing hypnosis can help with?
3. Why are memories recovered under hypnosis not trustworthy?

The answers are in the unit you just read.

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Unit 7.5: Conscious Vision



> **Image description:** Seen from behind a young woman's shoulder, a busy train station fills with blurred travelers. In the middle of the crowd, a smiling woman in a denim jacket waves, sharply in focus. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Learning Objectives

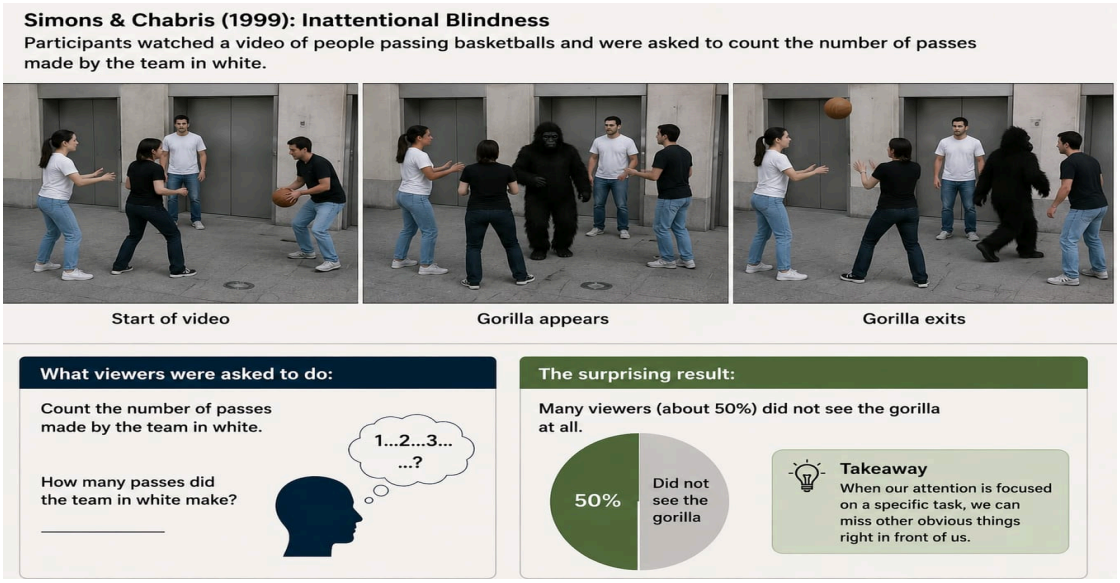
By the end of this unit, you will be able to:

- Define inattentional blindness and motion-induced blindness.
- Explain what blindsight suggests about awareness.

In a crowded train station you spot a friend waving, and everything else fades into the background. Your eyes take in far more than reaches awareness. Being conscious of something is not the same as your brain processing it.

Missing What's in Front of You

In a famous study, people counted basketball passes in a video. About half never noticed a person in a gorilla suit who walked through the game (Simons & Chabris, 1999). Failing to see something obvious because your attention is elsewhere is called **inattentional blindness**. Even full attention isn't enough: in **motion-induced blindness**, bright dots you are staring at seem to vanish when a moving pattern surrounds them (Bonneh et al., 2001).



> **Image description:** An infographic titled “Simons & Chabris (1999): Inattentional Blindness.” Three re-created scenes show people passing basketballs: the start of the video, a person in a gorilla suit walking into the middle of the game, and the gorilla leaving. A panel explains that viewers were asked to count the passes made by the team in white. A pie chart shows the result: about 50% of viewers did not see the gorilla at all. A takeaway reads, “When our attention is focused on a specific task, we can miss other obvious things right in front of us.” The scenes are artistic re-creations, not frames from the original video.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Seeing Without Knowing: Blindsight

People with damage to the primary visual cortex (V1, Module 5) are blind in part or all of their visual field. Yet some can point to or “guess” the location or movement of objects they say they can’t see, well above chance. This is called **blindsight** (Weiskrantz et al., 1974).

One man, blind after two strokes destroyed V1 on both sides, walked down a hallway cluttered with boxes and chairs and stepped around every one, though he said he saw nothing (de Gelder et al., 2008). Other visual pathways, like the one to the superior colliculus, still guide behavior without awareness.

So what makes vision conscious? One clue: when researchers briefly disrupted signals sent back from the motion area (V5) to V1, people stopped seeing motion (Pascual-Leone & Walsh, 2001). Many scientists think awareness depends on brain areas sharing information back and forth, not on any single spot.

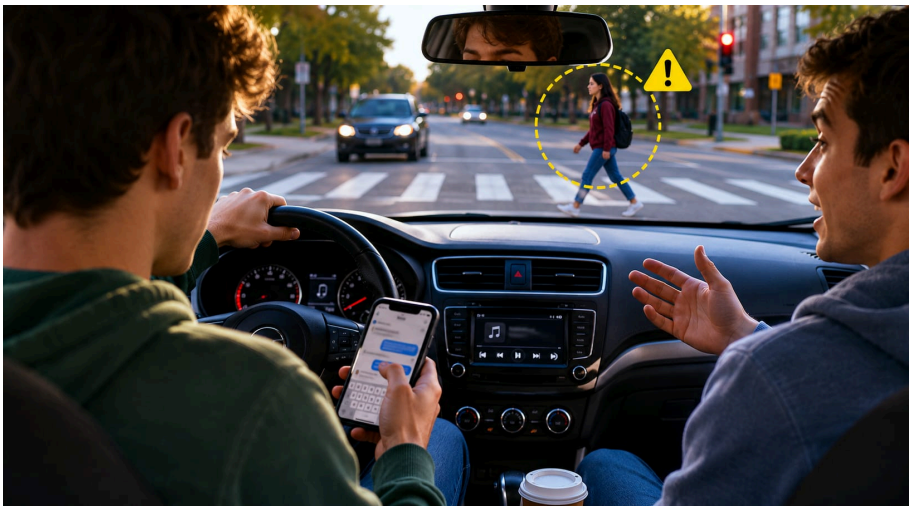
Check Your Understanding

1. What is inattentional blindness?
2. What is blindsight, and what brain damage causes it?
3. What does blindsight show about vision and awareness?

The answers are in the unit you just read.

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Unit 7.6: Introduction to Attention



> **Image description:** From the back seat of a car, a young driver holds a phone with a text conversation while his passenger talks and gestures. Through the windshield, a pedestrian is crossing the street in a crosswalk, circled in yellow with a warning symbol. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Learning Objectives

By the end of this unit, you will be able to:

- Define attention.
- Compare sustained, selective, and divided attention.

"Pay attention!" You've heard it since grade school, but what is attention? In 1890, William James wrote that attention "implies withdrawal from some things in order to deal effectively with others." Attention means selecting some information and leaving the rest behind.

Picture driving while a friend talks. A pedestrian steps into the crosswalk, your attention snaps to her, and the conversation fades. That shift helps keep you safe. If you were texting too, you might miss her completely.

Psychologists describe three main kinds of attention:

- **Sustained attention** is keeping focus over time, like a lifeguard scanning the water. Research on it began with World War II radar operators, whose ability to spot signals dropped after about half an hour on watch (Mackworth, 1948).
- **Selective attention** is focusing on one thing while ignoring others, like one voice at a party.
- **Divided attention** is trying to attend to more than one thing at once, like driving while talking.

All three show the same lesson: attention is a limited resource. When one task takes more of it, less is left for anything else.

From a Peer

"I used to study with my phone face up. When I started putting it in another room, I finished in half the time."

Check Your Understanding

1. What did William James say attention involves?
2. Give an example of sustained attention.
3. What is divided attention?

The answers are in the unit you just read.

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Unit 7.7: Selective Attention

Learning Objectives

By the end of this unit, you will be able to:

- Describe how dichotic listening and shadowing are used to study attention.
- Compare Broadbent's filter model with Treisman's attenuation model.

At a noisy party you can follow one conversation and tune out the rest. Then someone across the room says your name, and your attention jumps. This mix of focus and alertness is **selective attention**, and the party example is called the **cocktail party effect** (you met it in Module 6 as a hearing skill). The artistic image below shows how your name can pull your attention away from what you're doing.



> **Image description:** In a lecture hall, a student types notes on a laptop. Two classmates whisper nearby, one saying, "Did you hear that quiz is moved up?" A dotted line shows the student's attention shifting toward them, with a thought bubble reading "My name?" A phone buzzes on the desk. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

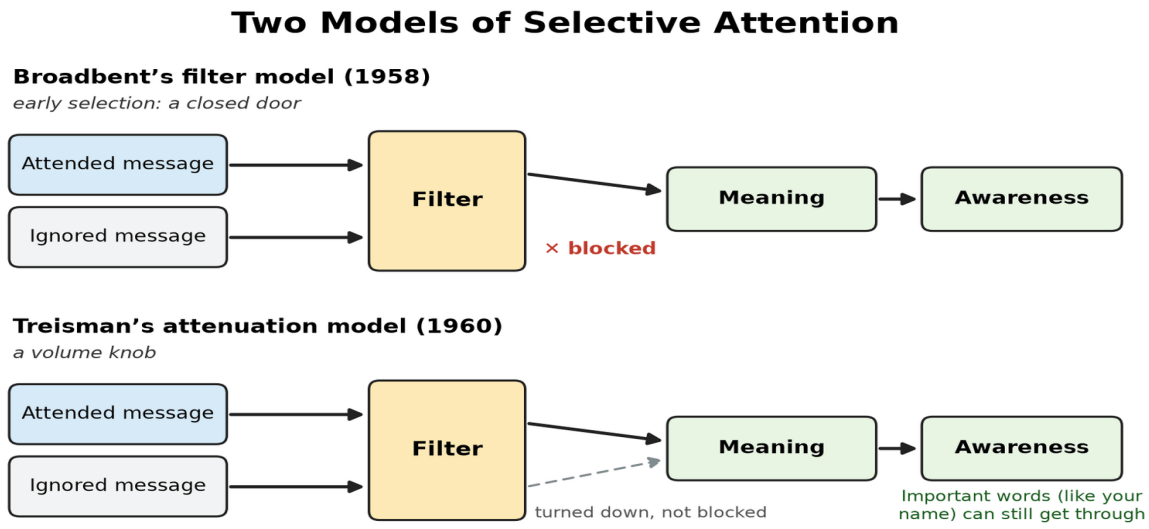
Studying It in the Lab

Early researchers used **dichotic listening**: people wore headphones playing a different message in each ear and repeated aloud, or **shadowed**, one of them. Afterward, they knew almost nothing about the ignored message. They noticed if the voice changed from male to female, but not if it switched languages (Cherry, 1953), and in a later study they didn't notice a word repeated 35 times (Moray, 1959). Yet about a third noticed their own name in the ignored ear (Moray, 1959).

Filter or Volume Knob?

Donald Broadbent (1958) proposed the **filter model**, an **early selection** idea: the brain picks one channel based on physical features, like which ear or what voice, and blocks the rest before its meaning is processed. But then how could your name get through?

Anne Treisman's experiments (1960) led her to the **attenuation model**. Ignored messages aren't blocked, just turned down. Important or expected words, like your name, need only a weak signal to be recognized, so they can still break through. In her studies, when a story jumped from the attended ear to the ignored one, people sometimes followed the story to the wrong ear without meaning to. The diagram below compares Broadbent's and Treisman's models.



> **Image description:** A two-row diagram. Top row, Broadbent's filter model: two messages, one attended and one ignored, reach a filter. Only the attended message passes through to meaning and awareness; the ignored message is blocked. Bottom row, Treisman's attenuation model: the ignored message is not blocked but passes through as a weaker, dashed signal. Most of it fades, but important words, such as your own name, can still reach meaning and awareness.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

In Plain Words

Broadbent's filter is a closed door: ignored sounds don't get in. Treisman's is a volume knob: ignored sounds are turned down, but loud or important ones, like your name, still come through.

Check Your Understanding

1. What is shadowing in a dichotic listening task?
2. What did Broadbent's filter model predict about the ignored message?
3. How does the attenuation model explain hearing your own name?

The answers are in the unit you just read.

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Unit 7.8: Divided Attention and Multitasking

Learning Objectives

By the end of this unit, you will be able to:

- Explain why most multitasking is really task switching, and describe its costs.
- Explain why talking or texting while driving is dangerous.

Many people say they're great at multitasking. Research says that most of the time we aren't doing two things at once. We're switching back and forth, and each switch costs time and accuracy. The artistic image below shows how many demands can compete for attention at once.



> **Image description:** A student at a desk talks on a phone pressed to his shoulder while typing on a second phone and writing notes. Notifications pop up around him: a message from Mom, a calendar reminder for a study group, and an email saying a quiz moved to Thursday. A whiteboard behind him shows a study plan. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Can Practice Help?

In a classic study, two students practiced reading stories while writing down words someone read aloud to them. After 17 weeks of practice, they could do both with little loss in reading speed or comprehension (Spelke et al., 1976). Practice can make a skill so automatic that it needs little attention, but that takes a lot of training on one specific pair of tasks.

The Cost of Switching

For most tasks, "multitasking" is really **task switching**. Each time you switch, your brain has to drop one set of rules and load another, and that takes time and causes errors (Monsell, 2003). This is why checking a notification "for just a second" can break your concentration.

Driving Distracted

Talking on a phone while driving, even hands-free, slows reactions and makes drivers miss brake lights, signs, and pedestrians, because the conversation itself takes attention (Strayer & Drews, 2007). Texting is worse, because it takes your eyes off the road too: at 55 mph, a 5-second glance at your phone means driving the length of a football field blind (National Highway Traffic Safety Administration, n.d.). In one study, only 5 of 200 drivers, about 2.5%, could talk on a phone without any loss in driving performance (Watson & Strayer, 2010).

Close to Home

Highway 198 and the two-lane roads around Coalinga have long, straight stretches that make it tempting to glance at a text, plus farm equipment and sudden curves where a few seconds matter. Put the phone out of reach before you start the car.

From a Peer

“I really believed I was a good multitasker until I tried a driving simulator in class and missed a stop sign.”

Check Your Understanding

1. What is task switching, and why does it cost time?
2. Why is a hands-free phone call still distracting while driving?
3. About what share of drivers can talk on a phone with no loss in driving performance?

The answers are in the unit you just read.

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Unit 7.9: Module Wrap-Up

You made it through Module 7. Before you move on to drive states like hunger, thirst, and body temperature, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Consciousness is your awareness of yourself and your surroundings, and scientists study it by combining what people report experiencing with outside measures such as brain activity, reaction times, and eye movements (7.1).
- Your brain processes far more than you notice, as priming shows, but some famous priming findings have not held up, and a single IAT score shouldn't be used to label a person as biased (7.2).
- High awareness, like mindfulness, takes effort but lets you catch a snap judgment or bring your focus back, and mindfulness training reliably reduces stress (7.2).
- Your circadian rhythm is set by a master clock in the hypothalamus called the suprachiasmatic nucleus, which light resets each day and which signals the pineal gland to release melatonin in the evening (7.3).
- You cycle through NREM and REM sleep about every 90 minutes, adults need at least 7 hours a night, and common sleep disorders like insomnia, sleep apnea, and narcolepsy are treatable (7.3).
- Hypnosis is a state of focused, absorbed attention in which people respond more readily to suggestions, and it can help reduce pain, but it doesn't make people act against their values or reliably uncover hidden memories (7.4).
- Inattentional blindness shows that you can miss something obvious when your attention is elsewhere, and blindsight shows that the brain can guide behavior without conscious vision (7.5).
- Attention is a limited resource, whether you are keeping focus over time (sustained attention), focusing on one thing (selective attention), or trying to split it between tasks (divided attention) (7.6).
- Broadbent's filter model said ignored messages are blocked, while Treisman's attenuation model says they are only turned down, which is why your own name can still break through (7.7).
- Most "multitasking" is really task switching, which costs time and accuracy, and even a hands-free phone call slows a driver's reactions (7.8).

Why This Module Matters

Attention and sleep shape almost everything you do, from how well you learn to how safely you drive. Night shifts, early packing-house start times, and hot summer nights can all fight your body clock, so steady sleep times and a dark, cool bedroom matter.

On the long, straight stretches of Highway 198 and the two-lane roads around Coalinga, one glance at a text can mean missing farm equipment or a sudden curve. And knowing that attention is limited can change how you study: putting your phone in another room isn't a weakness. It's working with your brain instead of against it.

Module 7 ideas in everyday life

Idea	Where you met it	Where you might see it
Circadian rhythm	7.3	Feeling off after a night shift, jet lag, or a late night on a bright screen
Sleep disorders	7.3	Loud snoring or trouble falling asleep that is worth raising with a health care provider
Inattentional blindness	7.5	Missing something obvious because you were focused on something else
Cocktail party effect	7.7	Hearing your name from across a noisy room
Task switching	7.8	Losing your place after checking a notification "for just a second"
Distracted driving	7.8	Putting your phone out of reach before you start the car

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Think about your sleep over the last week. What helps you sleep well, and what gets in the way: work, noise, light, screens, or something else?
2. When do you feel most focused during the day? How could you plan your hardest tasks for that time?
3. Think of a time you missed something obvious because your attention was somewhere else. What were you focused on?
4. Where in your life do you try to multitask most? What might happen if you tried doing one thing at a time there?

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Unit 7.10: References

About This Module

This module was adapted and rewritten by Michael Miguel from his earlier Consciousness and Attention module, which drew on the Noba modules States of Consciousness by Robert Biswas-Diener and Jake Teeny, Consciousness by Ken Paller and Satoru Suzuki, and Attention by Frances Friedrich, licensed CC BY-NC-SA 4.0. Changes: condensed and reorganized, a new unit on sleep and biological rhythms, plain language for Coalinga College campus and Rising Scholars students, Central Valley examples, review questions, corrected facts, and new diagrams. Material on psychoactive drugs moved to Module 13. Terms are defined in the book Glossary.

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MODULE 8: INTERNAL REGULATION AND DRIVE STATES



> **Image description:** An artistic poster titled "Internal Regulation and Drive States: How the body and mind maintain balance and motivate behavior." A woman drinks from a water bottle on a dry, sunny hillside, with a healthy bowl of food and a notebook nearby. A curved line links six labeled icons: homeostasis (maintaining a stable internal environment), physiological needs (hunger, thirst, temperature, rest), internal feedback (signals from the body guide action), drive states (motivational conditions that energize behavior), motivation (drives push us toward goals and relief), and balance and adaptation (restoring equilibrium through behavior). This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Think about the last time you were really hungry, really thirsty, or stuck outside on a 105-degree afternoon. It probably got hard to think about anything else. That pull comes from your body's built-in systems for keeping you alive.

In this module, you'll see how your body keeps things like energy, water, and temperature in a safe range, and how it uses feelings such as hunger and thirst to get you to act. You'll also learn why these feelings can take over your attention, how your brain decides when to start and stop eating, and how to spot the warning signs of heat illness.

Learning Objectives

By the end of this module, you will be able to:

- Define drive states and homeostasis, and explain what a set point is.
- Describe how strong drive states narrow attention and make people more impatient.
- Identify the main signals that start and stop eating and the role of the hypothalamus.
- Explain how outside cues, such as smells and the clock, affect hunger.
- Compare osmotic thirst and hypovolemic thirst.
- Describe how the hypothalamus keeps body temperature steady, and recognize the warning signs of heat exhaustion and heat stroke.

Unit 8.1: Introduction to Drive States

Unit 8.2: Key Properties of Drive States

Unit 8.3: Hunger and Eating

Unit 8.4: Thirst and Body Temperature
Unit 8.5: Module Wrap-Up
Unit 8.6: References

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Unit 8.1: Introduction to Drive States

Learning Objectives

By the end of this unit, you will be able to:

- Define a drive state and give examples.
- Explain the two jobs drive states do.

What's the longest you've gone without eating? As hunger grows, it gets harder to ignore. Food takes over your thoughts, your energy drops, and your focus shifts to getting something to eat. Once you eat, your body relaxes and your mind clears.

That experience is a **drive state**: a feeling created by a body need that pushes you to act. Hunger, thirst, feeling too hot or too cold, and sexual arousal (covered in Module 9) are all drive states. Each is linked to survival or reproduction.

Drive states do two jobs. They keep your body's inner conditions steady, and they protect your long-term survival. Your body constantly checks things like fuel, water, and temperature. When something drifts out of range, a drive state kicks in. It changes how you think, feel, and act. Hunger, for example, makes the smell of pizza more tempting and pushes you to go find food.

Drive states remind you that a lot of what you do starts in your body. Knowing that can help you notice what your body is asking for, and decide when to act on it right away and when to pause first.

From a Peer

"During Ramadan, I fasted from sunrise to sunset for the first time. At first I couldn't stop thinking about food, and even studying was harder. After a few days, I got better at noticing what my body was telling me. When I broke my fast, that first sip of water felt amazing."

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Unit 8.2: Key Properties of Drive States

Learning Objectives

By the end of this unit, you will be able to:

- Define homeostasis and set point.
- Explain how drive states narrow attention and make people impatient.

Drive states are different from emotions like joy or anger. Emotions often respond to what's happening around you. Drive states respond to what your body needs. Hunger pushes you to eat, and thirst pushes you to drink. Even so, all drive states share a few key features.

Homeostasis: Staying in a Safe Range

Homeostasis is the body's tendency to keep its inner conditions steady. The physiologist Walter Cannon named it and described how it works (Cannon, 1929). Each condition has a **set point**, a target level the body tries to hold, such as a body temperature near 98.6°F. Your body compares where you are with the set point and works to close the gap. Too little water is dangerous, but so is far too much, so the goal is balance.

Many of these corrections happen automatically, like your heart rate and blood pressure adjusting when you stand up. Others need you to act, and that's where drive states come in. Drifting out of balance feels bad, like a growling stomach or a dry mouth, and that discomfort pushes you to do something. Fixing the problem feels good, which makes you more likely to do the same thing next time.

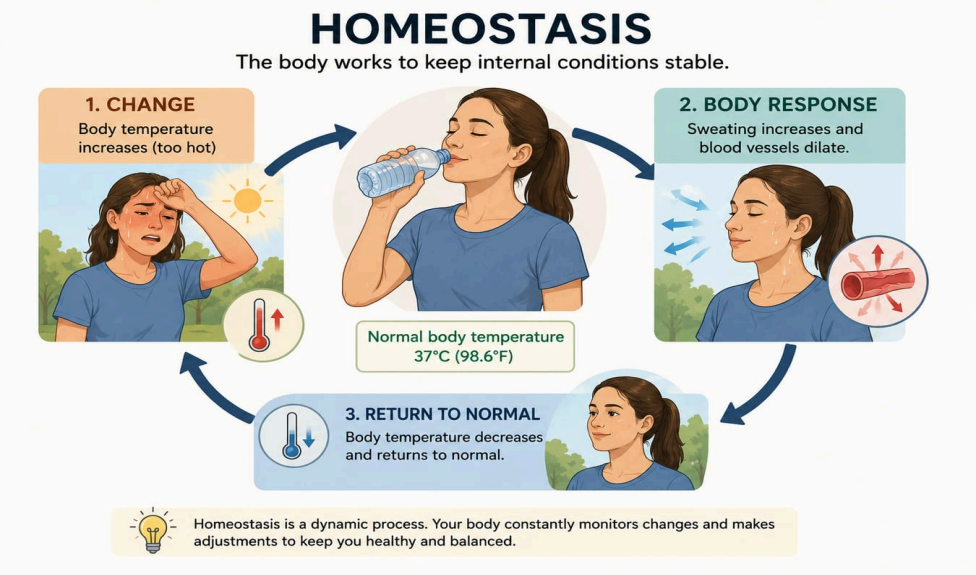


Image description: An infographic titled "Homeostasis: The body works to keep internal conditions stable." Three steps form a loop around a woman drinking water, with normal body temperature labeled 37°C (98.6°F). Step 1, Change: body temperature increases (too hot), shown by a woman wiping her forehead in the sun. Step 2, Body response: sweating increases and blood vessels dilate. Step 3, Return to normal: body temperature decreases and returns to normal. A note says homeostasis is a dynamic process in which the body constantly monitors changes and makes adjustments.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

In Plain Words

Your body works like the thermostat in a house. The thermostat is set to a temperature. When the room gets too hot, it turns on the air conditioning. When the room gets too cold, it turns on the heat. Drive states are the part of the system that gets *you* to help, like the urge to grab a jacket or a glass of water.

Drives Narrow Your Attention

The stronger a drive state gets, the more it takes over your attention. When you're thirsty, you notice every water fountain. Drives also change what you value. In one study, people whose hunger was stirred up with a snack of popcorn rated food products more favorably, and rated unrelated products, such as shampoo, as less appealing (Brendl et al., 2003). Strong hunger, thirst, or pain can also make it harder to think about other people's needs.

Drives Make You Impatient

Drive states pull your focus to right now. In one study, young men who had just looked at sexy photos or handled lingerie became more impatient about money, choosing a smaller payment now over a larger one later (Van den Bergh et al., 2008). People in treatment for opioid dependence showed the same pattern: when they were craving the drug, they also put less value on money they would get later (Giordano et al., 2002). You'll learn more about cravings in Module 13.

From a Peer

"I skipped lunch to finish a paper due at 2:00. By noon, all I could think about was food. I couldn't write a single good sentence until I grabbed a sandwich. Then my focus came right back."

Check Your Understanding

1. What is homeostasis?
2. What is a set point?
3. In the popcorn study, how did hungry people rate products that had nothing to do with food?
4. Besides narrowing attention, what other change do strong drive states cause?

The answers are in the unit you just read.

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Unit 8.3: Hunger and Eating

Learning Objectives

By the end of this unit, you will be able to:

- Describe signals that start eating, such as ghrelin, and signals that stop eating, such as leptin.
- Explain the role of the hypothalamus, including the lateral and ventromedial areas.
- Give examples of outside cues that affect eating.

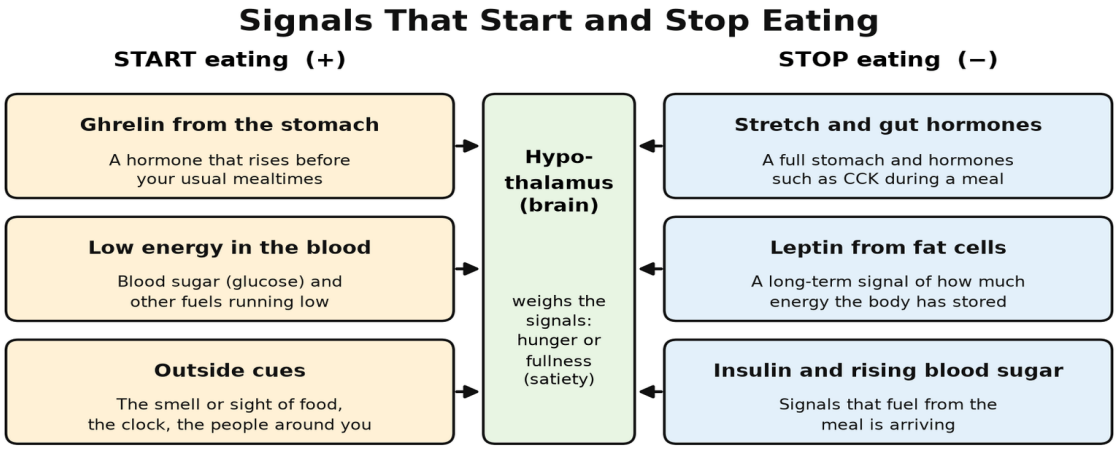
Why does your stomach growl at noon, even after a late breakfast? Hunger isn't just an empty stomach. It's a conversation between your gut, your fat cells, your blood, and your brain, with the outside world joining in.

Signals That Start Eating

Hunger is the drive state that pushes you to eat. One of its main signals is **ghrelin**, a hormone made mostly in the stomach. Ghrelin levels rise before your usual mealtimes and drop after you eat (Cummings et al., 2001). Low levels of fuel in the blood, such as blood sugar (glucose), also push you to eat.

Signals That Stop Eating

Satiety is the feeling of fullness that ends a meal. During a meal, your stomach stretches and your gut releases hormones, such as cholecystokinin (CCK), that tell your brain to slow down. Insulin rises as fuel from the meal arrives. Over the long term, fat cells release **leptin**. The more fat the body has stored, the more leptin it makes, which tells the brain how much energy is in reserve (Friedman & Halaas, 1998). The diagram below sums up the signals that start and stop eating.



Simplified. Many brain areas and signals work together; these are some of the main ones.

> **Image description:** A diagram titled "Signals That Start and Stop Eating." On the left, three start-eating signals point to the hypothalamus: ghrelin from the stomach, a hormone that rises before your usual mealtimes; low energy in the blood, such as low blood sugar (glucose); and outside cues, such as the smell or sight of food, the clock, and the people around you. On the right, three stop-eating signals point to the hypothalamus: stomach stretch and gut hormones such as CCK during a meal; leptin from fat cells, a long-term signal of stored energy; and insulin and rising blood sugar. The hypothalamus weighs the signals to produce hunger or fullness (satiety). The diagram is simplified.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

The Hypothalamus: Where the Signals Meet

These signals meet in the **hypothalamus**, a small area at the base of the brain that helps control hunger, thirst, and body temperature. Early studies with rats pointed to two key regions. When the **lateral hypothalamus** was damaged, rats stopped eating and drinking and could starve unless they were fed by tube, although many slowly recovered (Teitelbaum & Epstein, 1962). When the **ventromedial hypothalamus** was damaged, rats overate and gained a lot of weight (Hetherington & Ranson, 1940).

For years, textbooks called these the brain's "start eating" and "stop eating" centers. Scientists now know that's too simple. Networks of neurons in and around the hypothalamus read many signals at once, including ghrelin and leptin, and they work with the brain's reward and learning systems (Woods, 2009).

Outside Cues

Your surroundings matter too. Many people feel hungry at their usual lunchtime even if they ate recently, and the smell or sight of food can make you hungry right after a meal. Our hunger system evolved when food was often scarce. Today, cheap, tasty food is everywhere, and that mismatch helps explain why it's so easy to overeat.

Close to Home

Drive past a taco truck in Coalinga, or smell tri-tip on the grill at a Friday night football game, and you may suddenly feel hungry, even if you just ate. That's an outside cue at work. Your brain has learned that the smell means food is close, and it gets your body ready to eat.

From a Peer

"For a long time my meals came at the same set times every day. Even now, my stomach starts growling right at 4:30, whether I'm hungry or not."

Check Your Understanding

1. Which hormone from the stomach rises before mealtimes?
2. What does leptin tell the brain?
3. What happened to rats with damage to the lateral hypothalamus?
4. Name one outside cue that can make you hungry.

The answers are in the unit you just read.

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Unit 8.4: Thirst and Body Temperature

Learning Objectives

By the end of this unit, you will be able to:

- Compare osmotic thirst and hypovolemic thirst, and describe the role of vasopressin.
- Explain how the body keeps its temperature steady, including fever.
- Distinguish heat exhaustion from heat stroke.

It's 3:00 on a July afternoon, and it's 105°F in the shade. You've been working or practicing outside since noon. Your mouth is dry, your shirt is soaked, and all you want is cold water and some shade. Two of your body's most important balancing acts, water and temperature, are working overtime.

Why You Get Thirsty

More than half of your body weight is water, and your body keeps that water in balance closely. There are two main kinds of thirst (Zimmerman et al., 2017).

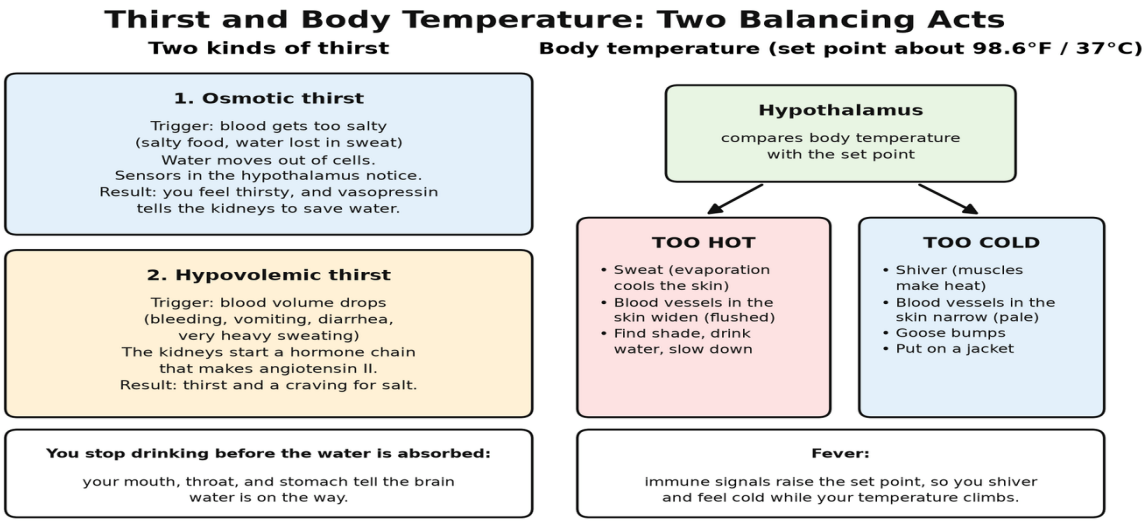
- **Osmotic thirst** happens when your blood gets too salty, for example after salty chips or after losing water in sweat. Water moves out of your cells, and sensors in the hypothalamus notice. You feel thirsty, and your pituitary gland releases **vasopressin** (also called antidiuretic hormone), which tells your kidneys to save water.
- **Hypovolemic thirst** happens when the amount of blood drops, for example from bleeding, vomiting, diarrhea, or very heavy sweating. Your kidneys start a chain of hormones that makes angiotensin II, which triggers thirst and a craving for salt.

You usually stop drinking before the water has had time to reach your blood. Your mouth, throat, and stomach tell your brain that water is on the way. Drinking far too much water very quickly can also be dangerous, because it dilutes the salt in your blood.

Keeping Your Temperature Steady

Your core body temperature stays near 98.6°F (37°C), though a normal temperature varies a bit from person to person and over the day. The hypothalamus works as your thermostat, comparing your temperature with its set point (Morrison & Nakamura, 2019). When you're too hot, you sweat, and the evaporating sweat cools your skin. The blood vessels in your skin also widen to release heat. When you're too cold, you shiver to make heat, and the blood vessels in your skin narrow to keep heat in.

Temperature is also a drive state. Feeling hot pushes you to find shade, drink water, and slow down, and feeling cold pushes you to grab a jacket. During a **fever**, signals from your immune system raise the set point. That's why you can shiver and feel cold while your temperature is climbing.



Simplified diagram.

> **Image description:** A two-part diagram. Left, two kinds of thirst. Osmotic thirst: blood gets too salty (from salty food or water lost in sweat), water moves out of cells, sensors in the hypothalamus notice, and you feel thirsty while vasopressin tells the kidneys to save water. Hypovolemic thirst: blood volume drops (from bleeding, vomiting, diarrhea, or very heavy sweating), and the kidneys start a hormone chain that makes angiotensin II, causing thirst and a craving for salt. A note says you stop drinking before the water is absorbed, because your mouth, throat, and stomach tell the brain water is on the way. Right, body temperature, with a set point of about 98.6°F (37°C): the hypothalamus compares body temperature with the set point. Too hot: sweat, blood vessels in the skin widen, and you find shade, drink water, and slow down. Too cold: shiver, blood vessels in the skin narrow, goose bumps, and you put on a jacket. A note explains that in a fever, immune signals raise the set point, so you shiver and feel cold while your temperature climbs.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

When Heat Wins

If your body can't get rid of heat fast enough, heat illness can follow. **Heat exhaustion** brings heavy sweating, dizziness, headache, nausea, and weakness. Move to shade, cool off, and drink water. **Heat stroke** is a medical emergency. Body temperature reaches about 104°F (40°C) or higher, and the person becomes confused, faints, or has a seizure. Their skin may be hot and dry or still sweaty. Call 911 and cool the person right away (Epstein & Yanovich, 2019).

Close to Home

California has rules to protect people who work outside in the heat (California Department of Industrial Relations, n.d.). Employers must provide enough fresh, cool water for each worker to drink at least one quart per hour, provide shade when it's over 80°F, and let workers take a cool-down rest in the shade whenever they need one. At 95°F or above, farms, construction sites, and oil and gas work must follow extra high-heat steps, such as watching workers for signs of heat illness.

Key Takeaways

- Drive states push you to act when your body drifts away from a set point.
- Hunger and fullness come from signals like ghrelin, leptin, and stomach stretch, weighed by the hypothalamus.
- Osmotic thirst responds to salty blood; hypovolemic thirst responds to low blood volume.
- The hypothalamus keeps your temperature steady, and heat stroke is an emergency.

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Unit 8.5: Module Wrap-Up

You made it through Module 8. Before you move on to hormones, relationships, and love, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- A drive state is a feeling created by a body need, like hunger, thirst, or feeling too hot or too cold, that pushes you to act, both to keep your body's inner conditions steady and to protect your survival (8.1).
- Homeostasis is the body's tendency to keep its inner conditions steady around a set point, much like a thermostat, and drive states are the part of the system that gets you to help (8.2).
- The stronger a drive state gets, the more it takes over your attention, changes what you value, and makes you more impatient about the future (8.2).
- Ghrelin from the stomach helps start eating, while stomach stretch, gut hormones, insulin, and leptin from fat cells help stop it, and these signals meet in the hypothalamus (8.3).
- Early rat studies pointed to "start eating" and "stop eating" centers in the hypothalamus, but scientists now know that networks of neurons read many signals at once and work with the brain's reward and learning systems (8.3).
- Outside cues, like the smell of food or your usual lunchtime, can make you hungry even right after you eat (8.3).
- Osmotic thirst responds to blood that is too salty, and hypovolemic thirst responds to a drop in the amount of blood (8.4).
- The hypothalamus works as your thermostat, using sweating and shivering to keep you near 98.6°F, and heat stroke, with confusion and a body temperature of about 104°F or higher, is a medical emergency (8.4).

Why This Module Matters

In the Central Valley, these ideas are a matter of health and safety. On a 105-degree afternoon, your body is working overtime to stay cool, and knowing the signs of heat exhaustion and heat stroke can help you protect yourself, your coworkers, and your family. California has rules that require water, shade, and cool-down rest for people who work outside in the heat. Drive states also explain everyday moments, like why it's hard to write a paper when you skipped lunch, or why the smell of tri-tip at a Friday night game makes you hungry even after dinner.

Module 8 ideas in everyday life

Idea	Where you met it	Where you might see it
Drives narrow attention	8.2	Not being able to focus on a paper until you eat something
Outside cues	8.3	Feeling hungry when you drive past a taco truck, even if you just ate
Osmotic thirst	8.4	Feeling thirsty after salty chips or a long, sweaty shift
Heat exhaustion	8.4	Heavy sweating, dizziness, and a headache: move to shade, cool off, and drink water
Heat stroke	8.4	Confusion or fainting in the heat: call 911 and cool the person right away
California heat rules	8.4	Employers providing water, shade, and cool-down rest for people who work outside

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Think of a time hunger, thirst, or heat took over your attention. How did it change your mood, your patience, or your choices?
2. What outside cues make you hungry, like certain smells, places, or times of day? Had you noticed them before reading this

module?

3. How do you stay cool and hydrated on the hottest days, at work, at school, or at home? Is there anything you'd change now that you know the signs of heat illness?
4. Drive states can make you impatient. When is it worth pausing before you act on a strong urge, and what helps you pause?

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Unit 8.6: References

About This Module

This module was adapted and rewritten by Michael Miguel from his earlier Internal Regulation and Drive States module, which drew on the Noba module *Drive States* by Sudeep Bhatia and George Loewenstein, licensed CC BY-NC-SA 4.0. Changes: rewritten in plain language for Coalinga College campus and Rising Scholars students; the material on sexual arousal moved to Module 9; new sections on hunger signals, thirst, body temperature, and heat illness; Central Valley examples added; facts checked and corrected. The web addresses below are for reference only; you don't need them to use this book.

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MODULE 9: HORMONES, SEX, AND LOVE



> **Image description:** An artistic collage titled “Everything Love & Sex: Connection. Intimacy. Human Nature.” A young woman rests her chin on her hand, thinking, over an open notebook. Around her are couples, groups of friends, a glowing brain labeled with dopamine, oxytocin (bonding), and vasopressin (attachment), and short lists under the headings Biological Foundations, Attraction and Desire, Love and Relationships, Sexuality, and Health, Consent and Boundaries. A banner at the bottom reads “Love is complex. Human. Powerful.” This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Why does winning a game make you feel ten feet tall? Why do new parents feel such a strong pull to protect their baby? Why does a hug from the right person make a terrible day feel better? Part of the answer is hormones, chemical messengers that link your brain, your body, and your relationships.

In this module, you’ll see how hormones shape sex differences, aggression, parenting, sexual behavior, and love, and how your experiences change your hormones in return. You’ll also see why biology never tells the whole story: culture, learning, and choice always play a part.

Learning Objectives

By the end of this module, you will be able to:

- Explain how hormones affect behavior and how behavior and experience affect hormones.
- Compare the organizational and activational effects of hormones.
- Describe sex differences in behavior, and explain why the overlap between groups matters.
- Describe how testosterone relates to aggression, and explain why hormones don’t determine behavior.
- Identify the hormones and brain areas involved in parenting and in sexual behavior.
- Explain how oxytocin and vasopressin support bonding, using prairie vole research as an example.
- Describe how social support affects the stress response and health, and what oxytocin research can and can’t show yet.

Unit 9.1: Hormones and Behavior

Unit 9.2: Sex Differences

Unit 9.3: Aggression

Unit 9.4: Parental Behavior
Unit 9.5: Sexual Behavior and the Brain
Unit 9.6: The Evolution of Social Behavior
Unit 9.7: Stress and Love
Unit 9.8: Can Love or Oxytocin Be a Medicine?
Unit 9.9: Module Wrap-Up
Unit 9.10: References

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Unit 9.1: Hormones and Behavior

Learning Objectives

By the end of this unit, you will be able to:

- Define behavioral endocrinology.
- Explain how hormones affect behavior and how behavior and experience affect hormones.

Think about the last time you won something, like a game, an argument, or a job offer. You probably felt bigger, more confident, maybe even a little cocky. That feeling isn't only in your head. It's also in your blood.

Hormones are chemical messengers that glands release into the bloodstream. They travel all over the body, but they only affect cells that have the right receptors, as you saw with the endocrine system in Module 2. **Behavioral endocrinology** is the study of how hormones and behavior affect each other.

That influence runs both ways. Hormones change behavior: higher testosterone, for example, is linked to more interest in sex. But behavior and experience also change hormones. A stressful exam raises cortisol, and men's testosterone tends to drop after they become fathers and start caring for a baby (Gettler et al., 2011). Hormones don't force a behavior. They make some behaviors more or less likely, depending on the situation.

Some hormones you'll meet in this module

Hormone	Made mainly in	Some of its roles
Testosterone	Testes (smaller amounts in ovaries and adrenal glands)	Sexual development, sex drive, muscle, competition
Estradiol	Ovaries (smaller amounts in testes)	Reproductive cycle, sexual development, brain development
Prolactin	Pituitary gland	Milk production, parenting
Oxytocin	Hypothalamus (released by the pituitary)	Childbirth, nursing, bonding, trust
Vasopressin	Hypothalamus (released by the pituitary)	Saving water, social memory, pair bonding
Cortisol	Adrenal glands	Stress response, energy

In Plain Words

Think of a hormone as a group text sent to the whole body. Every cell gets the message, but only the cells with the right "app" (a receptor) can open it and respond.

Check Your Understanding

1. What is behavioral endocrinology?
2. Give one example of experience changing hormone levels.
3. Which gland makes cortisol?

The answers are in the unit you just read.

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Unit 9.2: Sex Differences

Learning Objectives

By the end of this unit, you will be able to:

- Distinguish sex, gender, and gender identity, and define sexual dimorphism.
- Explain how the SRY gene and prenatal hormones start sexual development, and how development can vary.
- Compare organizational and activational effects of hormones, and describe what research shows about the size of sex differences.

Are men and women really from different planets? Not even close. But there are some real average differences, and biology and culture both help explain them.

In science, **sex** refers to biological traits such as chromosomes, hormones, and reproductive organs. **Gender** refers to the roles, expectations, and identities a culture builds around sex. **Sexual dimorphism** means physical or behavioral differences between the sexes of a species, like the male peacock's tail. Humans show much less of it than many animals.

How Hormones Shape Development

Sexual development starts with the chromosomes. Of the 46 chromosomes in each cell, two are sex chromosomes: girls and women typically have two X chromosomes (XX), and boys and men typically have one X and one Y (XY). A gene on the Y chromosome called **SRY** (sex-determining region Y) makes a protein that starts the processes that lead a fetus to develop testes and keeps a uterus and fallopian tubes from forming (MedlinePlus, n.d.).

Before birth, the testes of a male fetus make androgens, a group of hormones that includes testosterone. These hormones guide the body, and parts of the brain, toward a male pattern. Without high androgen levels, development generally follows a female pattern. These early, lasting changes are called **organizational effects**. In classic studies with guinea pigs, females exposed to testosterone before birth later acted more like males in mating behavior, even as adults (Phoenix et al., 1959).

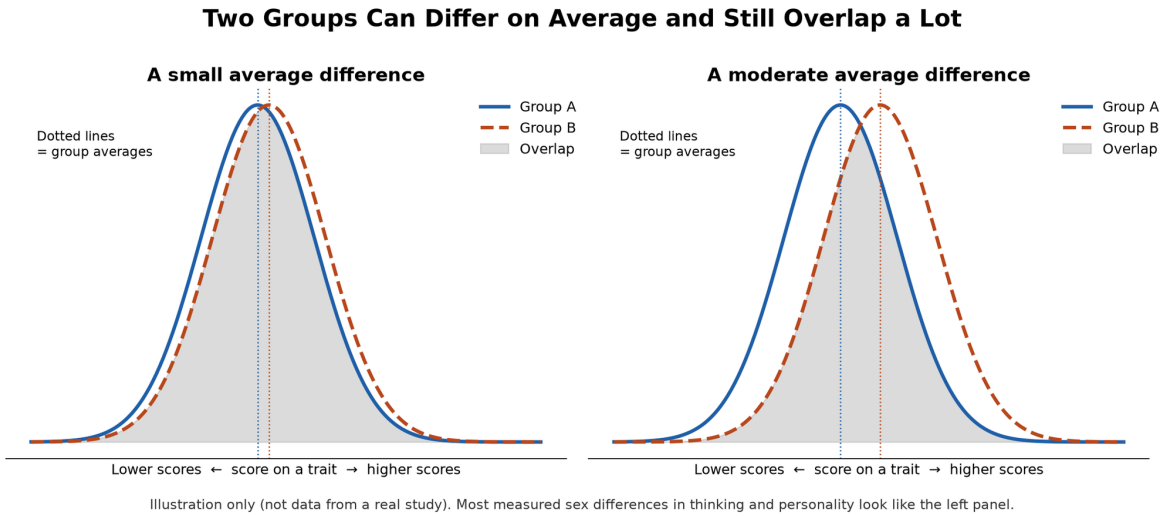
Later in life, hormones have **activational effects**: shorter-term changes that come and go as hormone levels rise and fall. The surge of hormones at puberty, for example, increases interest in sex.

Development doesn't always follow these typical patterns. Some people are born with **intersex** traits, also called differences of sex development (DSD), in which physical sex characteristics develop in less typical ways (American Psychological Association, 2024; MedlinePlus, 2026). For example, a person with XY chromosomes whose SRY gene doesn't work develops female-typical sex characteristics (MedlinePlus, n.d.). **Gender identity** is a person's internal sense of being male, female, or something else. People whose gender identity doesn't match what is typically associated with the sex they were assigned at birth may describe themselves as transgender (American Psychological Association, 2024).

Biology and Culture Together

In one study, male vervet monkeys spent more time with a toy car and a ball, while females spent more time with a doll and a cooking pot (Alexander & Hines, 2002). Because monkeys don't learn human gender rules, this hints that biology plays some role in toy choices. But the study was small, and culture clearly shapes what children are encouraged to play with.

On average, women do slightly better on some verbal tasks, and men do better on some tasks that involve mentally rotating objects. Most measured differences in thinking and personality, though, are small, and the two groups overlap a lot (Hyde, 2005). Knowing someone's sex tells you very little about that individual. The graphs below show how two groups can differ on average and still overlap a lot.



> **Image description:** Two side-by-side graphs titled “Two Groups Can Differ on Average and Still Overlap a Lot.” Each shows two bell-shaped curves, Group A as a solid line and Group B as a dashed line, with the shared area shaded gray and dotted lines marking each group’s average. In the left graph, labeled “A small average difference,” the curves almost completely overlap. In the right graph, labeled “A moderate average difference,” the averages are farther apart, but most of the two curves still overlap. A note says this is an illustration, not data from a real study, and that most measured sex differences in thinking and personality look like the left graph.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

From a Peer

“Learning about hormones and development changed how I think about sex and gender. I used to see them as two simple boxes. Now I see how biology, environment, and personal experience all mix together, and people are way more varied than the stereotypes.”

Check Your Understanding

1. What is the difference between sex and gender?
2. Are organizational effects temporary or lasting?
3. What do most measured sex differences in thinking look like?

The answers are in the unit you just read.

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Unit 9.3: Aggression

Learning Objectives

By the end of this unit, you will be able to:

- Define aggression.
- Describe the link between testosterone and aggression in animals and in people.
- Explain how learning, culture, and stress affect aggression.

Two dogs growl over a bone. Two players shove each other after a hard foul. **Aggression**, behavior meant to harm or dominate someone, shows up across the animal world. In many animals it helps defend territory, food, mates, and young. In people it can also cause real harm, which is why understanding it matters.

Testosterone and Aggression in Animals

In many species, aggression rises during mating season, when testosterone peaks. Removing the testes usually lowers aggression in male animals, and giving testosterone back usually restores it. Timing matters too. Male mice whose testes were removed right after birth were much less aggressive as adults, even when they were later given testosterone. Early hormones help organize the brain circuits that later hormones activate.

Aggression in People

On average, men commit more physical aggression than women, and the difference is smaller for verbal aggression (Archer, 2004). Higher average testosterone may play some part. So do learning and culture. Boys are often encouraged to roughhouse, while girls are more often discouraged from fighting.

Testosterone doesn't simply cause violence. It seems more closely linked to competing for status. In some studies, men's testosterone rose after winning a competition and fell after losing, although results vary from study to study (Mazur & Booth, 1998). Stress, lack of sleep, and pain can also make people quicker to snap.

Biology can make some reactions more likely, but it doesn't remove choice. People can learn skills that change how they handle anger, like walking away, cooling down, or talking it out.

Close to Home

On a 108-degree August afternoon in the Valley, tempers can run short. Researchers have linked hot temperatures to more irritability and aggression (Anderson, 2001). It's a good reminder that body states, not just hormones, shape how we react, and that shade, water, and a cool-down break help in more ways than one.

From a Peer

"I used to think aggression was just anger or personality. It surprised me that testosterone doesn't automatically make people violent. Stress, the people around you, and what you've learned all play a part, and you still get to choose what you do."

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Unit 9.4: Parental Behavior

Learning Objectives

By the end of this unit, you will be able to:

- Describe how hormones and experience trigger parental behavior in rats, including the roles of prolactin and the medial preoptic area.
- Describe how parents' hormones change with a new baby.

A newborn can't feed itself, keep itself warm, or run from danger. For many animals, including humans, survival depends on **parental behavior**: feeding, protecting, cleaning, comforting, and teaching young. Mothers usually provide most of the care in mammals because of pregnancy and nursing, but fathers and other relatives often help too.

Lessons From Rats

Mother rats build nests, nurse, gather up pups that wander, and fiercely defend them. A female rat that has never been pregnant usually avoids pups at first, because they're new and unfamiliar. But if she is around pups every day, she starts caring for them within about a week (Rosenblatt, 1967). Experience alone can build parenting.

Hormones speed this up a lot. Late in pregnancy, progesterone drops while estradiol, **prolactin**, and oxytocin rise. This pattern helps switch on caregiving right at birth. A key brain area is the **medial preoptic area** of the hypothalamus, which is needed for mother rats to care for their young. The amygdala, which helps process fear, may at first make unfamiliar pups seem threatening, until hormones and experience calm that response.

Human Parents

Human parenting is shaped by hormones, learning, and culture together. In one small study of first-time mothers, those with higher cortisol a few days after birth were more affectionate with their babies. Mothers who had felt more positive about caring for children during pregnancy were also more affectionate (Fleming et al., 1987). Fathers change too. Men's testosterone tends to drop after they become fathers (Gettler et al., 2011), and fathers with lower testosterone felt more sympathy and a stronger need to respond when they heard a baby cry (Fleming et al., 2002).

Close to Home

In many Valley families, raising kids is a group effort. Grandparents, tías and tíos, and older siblings help feed, watch, and teach the little ones. Scientists call care from people other than the parents alloparenting, and it's one reason humans can raise children who need care for so many years (Hrdy, 2009).

Check Your Understanding

1. Name three parental behaviors of mother rats.
2. How long did it take females that had never been pregnant to start caring for pups?
3. Which area of the hypothalamus is key for maternal behavior?
4. What tends to happen to men's testosterone after they become fathers?

The answers are in the unit you just read.

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Unit 9.5: Sexual Behavior and the Brain

Learning Objectives

By the end of this unit, you will be able to:

- Describe sexual arousal as a drive state.
- Identify brain areas involved in sexual behavior, including the ventromedial hypothalamus and the reward system.
- Explain how strong arousal affects decision-making.

Like hunger and thirst, sex has its own drive state. **Sexual arousal** is a state of heightened sexual interest and readiness. It can be triggered from the inside, by hormones and thoughts, and from the outside, by sights, sounds, touch, and smell. Unlike hunger, you won't die without sex, but a species would.

Brain Areas for Sexual Behavior

Much of what we know comes from rodents. In males, the medial preoptic area of the hypothalamus (the same area that matters for parenting) is key. Male rats with damage there still approach and investigate a receptive female, but they rarely mate. Their interest remains, but the mating behavior mostly does not. In female rodents, the **ventromedial hypothalamus**, working with estradiol, controls whether a female is receptive to mating.

In humans, hormones matter, but less strictly. Testosterone is linked to sexual desire in both men and women, and people's sexual behavior depends heavily on emotions, relationships, culture, and values.

The Reward System

Sex, like food and water, activates the brain's reward system. In a famous 1954 study, rats pressed a lever over and over to get mild electrical stimulation to the septal area and other nearby brain regions (Olds & Milner, 1954). In a later study, some hungry rats that could choose between a food lever and a stimulation lever spent so much time on stimulation that they ate too little (Routtenberg & Lindy, 1965). Reward circuits are powerful motivators.

Decisions in the Heat of the Moment

Strong arousal changes decisions. In one study, college men answered questions about sex both while calm and while sexually aroused. When aroused, they said they'd be more willing to have unprotected sex and to do things they called unacceptable when calm, and when calm, they didn't predict how much arousal would change them (Ariely & Loewenstein, 2006). The takeaway: decide about consent, boundaries, and protection ahead of time, when your head is clear.

In Plain Words

Arousal works a lot like hunger at a grocery store. When you shop hungry, you grab things you wouldn't pick on a full stomach. Making your list before you go, while you're calm, keeps you on track.

Check Your Understanding

1. What is sexual arousal?
2. What happened to male rats with damage to the medial preoptic area?
3. In female rodents, which brain area works with estradiol to control receptivity?

> *The answers are in the unit you just read.*

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Unit 9.6: The Evolution of Social Behavior

Learning Objectives

By the end of this unit, you will be able to:

- Define eusociality and explain why group living can pay off.
- Describe how oxytocin and vasopressin support bonding.
- Explain what prairie vole studies showed about pair bonds.

Living with others has big advantages: protection from predators, shared food, and help raising young. That's why social behavior shows up all over the tree of life. Even bacteria send chemical signals to one another and build organized communities.

From Insect Colonies to Mammal Families

Ants, bees, and termites live in highly organized colonies with a division of labor and shared care of young, called **eusociality**. This lifestyle evolved separately several times, which suggests cooperation pays off.

Mammals took a different path. Unlike most reptiles, mammal mothers nurse their young, and nursing requires a close, lasting bond. That bond needed brain systems and hormones that make caring for others feel rewarding. Many mammals, including wolves, elephants, dolphins, and primates, form long-term relationships, and humans build especially complex ones with the help of empathy, language, and culture.

Oxytocin and Vasopressin

Two closely related hormones, both made in the hypothalamus, are central to bonding. **Oxytocin** causes contractions during childbirth and milk release during nursing, and inside the brain it supports bonding, trust, and caregiving. It's often called the "love hormone," but that nickname is too simple, as you'll see in Unit 9.8. **Vasopressin** helps the kidneys save water (Module 8), and in the brain it supports social memory, protecting a partner or territory, and pair bonding, especially in males. The diagram below shows where oxytocin and vasopressin work in the brain and body.

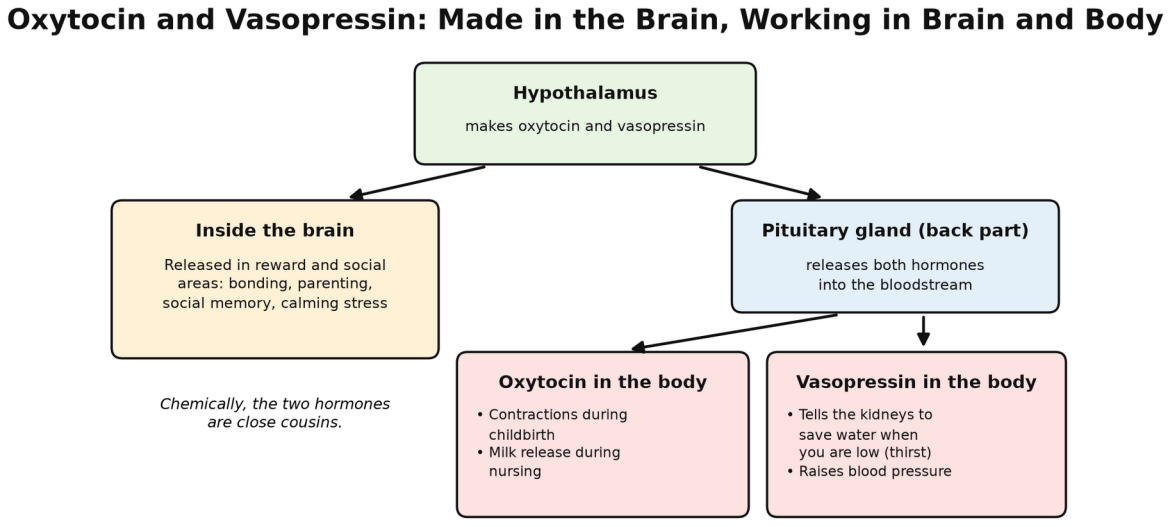


Image description: A diagram titled "Oxytocin and Vasopressin: Made in the Brain, Working in Brain and Body." The hypothalamus makes both hormones. One arrow leads to "Inside the brain," where they are released in reward

> and social areas and help with bonding, parenting, social memory, and calming stress. Another arrow leads to the back part of the pituitary gland, which releases both hormones into the bloodstream. From there, oxytocin causes contractions during childbirth and milk release during nursing, and vasopressin tells the kidneys to save water when you are low and raises blood pressure. A note says the two hormones are chemically close cousins.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Prairie Voles and the Chemistry of Commitment

Prairie voles are small rodents that form a **pair bond**, a lasting preference for one partner, after mating, and both parents help raise the pups. Only about 3% to 5% of mammal species live this way (Young et al., 2008). Their close relatives, meadow voles and montane voles, don't.

Prairie voles have more oxytocin and vasopressin receptors in the brain's reward areas. Blocking those receptors keeps prairie voles from forming pair bonds (Young & Wang, 2004). In a striking experiment, researchers added extra vasopressin receptors to a reward area in male meadow voles, and those males began to prefer their partners too (Lim et al., 2004). Even pair-bonded prairie voles sometimes mate with others, so a pair bond is about attachment, not perfect faithfulness.

Close to Home

Every February, beekeepers from around the country truck honeybee hives into the Valley's almond orchards. Honeybees are eusocial: thousands of workers split up the jobs of foraging, guarding, and caring for young, all for the good of the colony. Without their teamwork, much of the almond crop couldn't be pollinated.

Check Your Understanding

1. What is eusociality?
2. Name two jobs oxytocin does in the body.
3. What happened when researchers added vasopressin receptors to male meadow voles?

The answers are in the unit you just read.

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Unit 9.7: Stress and Love

Learning Objectives

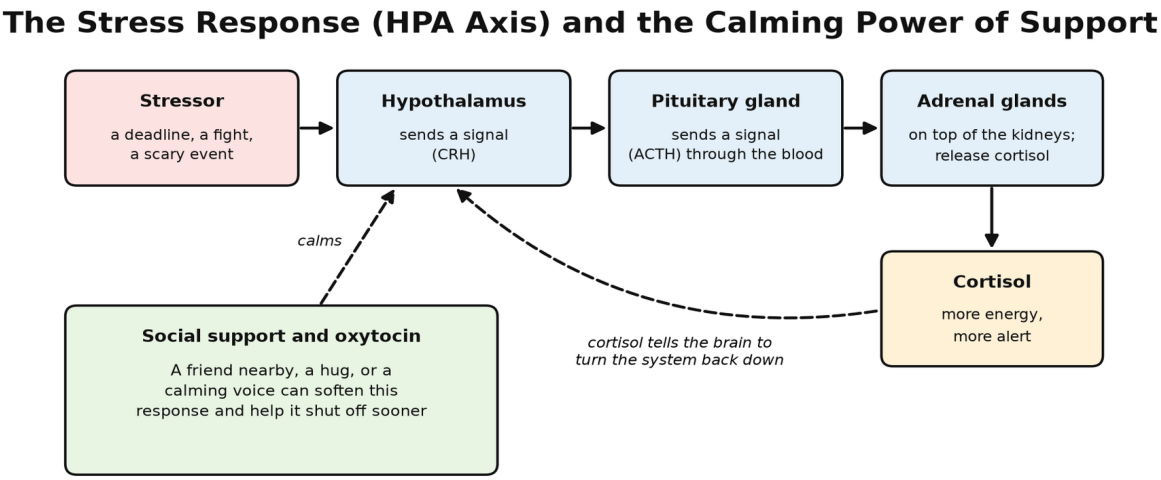
By the end of this unit, you will be able to:

- Describe the HPA axis.
- Explain the “tend and befriend” response.
- Describe how social support calms the stress response.

When something scary or painful happens, who do you call? For most people, the answer is someone they love. Humans are social animals, and for most of our history, sticking together during danger meant surviving it.

The Stress Response

When you face a stressor, your body turns on the **HPA axis** (hypothalamus, pituitary, adrenal). The hypothalamus signals the pituitary gland, which signals the adrenal glands to release cortisol, giving you energy to deal with the problem. Normally, cortisol then tells the brain to turn the system back down. You’ll learn more about stress and health in Module 10. The flowchart below shows this stress response and how support can calm it.



Simplified. H-P-A = hypothalamus, pituitary, adrenal. A short burst helps; a system that stays on for weeks can harm health.

> **Image description:** A flowchart titled “The Stress Response (HPA Axis) and the Calming Power of Support.” A stressor, such as a deadline, a fight, or a scary event, leads to the hypothalamus, which sends a signal (CRH) to the pituitary gland, which sends a signal (ACTH) through the blood to the adrenal glands on top of the kidneys. The adrenal glands release cortisol, which brings more energy and alertness. A dashed arrow shows cortisol telling the brain to turn the system back down. A second dashed arrow, labeled “calms,” runs from a box reading “Social support and oxytocin: a friend nearby, a hug, or a calming voice can soften this response and help it shut off sooner” to the hypothalamus. A note explains that HPA stands for hypothalamus, pituitary, adrenal, and that a short burst helps, but a system that stays on for weeks can harm health.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Tend and Befriend

Stress doesn't only trigger fight or flight. People also respond by protecting loved ones and reaching out to others, a pattern called **tend and befriend**. It may be more common in women, on average, and oxytocin may help drive it (Taylor et al., 2000).

Support really does calm the body. In one study, men gave a stressful speech in front of judges. Those who had a friend's support and a dose of oxytocin nasal spray had the lowest cortisol and felt the calmest (Heinrichs et al., 2003). Even pets count. When dogs and their owners gazed at each other, oxytocin rose in both (Nagasawa et al., 2015).

Oxytocin and vasopressin work as a team. Oxytocin is linked to calm, closeness, and caregiving, while vasopressin is linked to alertness and protecting loved ones. Together, they help balance nurturing and defending.

From a Peer

"When I was far away from my kids for a long stretch, our phone calls were the best part of my week. Ten minutes of hearing their voices could calm me down for the whole day."

Check Your Understanding

1. What does HPA stand for?
2. What is "tend and befriend"?
3. In the speech study, which group had the lowest cortisol?

The answers are in the unit you just read.

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Unit 9.8: Can Love or Oxytocin Be a Medicine?

Learning Objectives

By the end of this unit, you will be able to:

- Describe evidence linking relationships to health.
- Evaluate claims that oxytocin nasal spray works as a treatment.

People have talked about the healing power of love for centuries. Science is starting to test that idea, with some exciting results and some important letdowns.

Relationships and Health

Strong relationships are linked to a longer life. When researchers combined 148 studies, people with stronger social relationships were about 50% more likely to be alive at follow-up than people with weaker ones (Holt-Lunstad et al., 2010). Love may even help the body heal. In one study, couples who were warm and supportive toward each other had higher oxytocin levels, and those with higher oxytocin healed small skin wounds faster (Gouin et al., 2010).

Oxytocin is made in the hypothalamus, and its receptors are found in the heart and many other organs as well as the brain. That's one reason scientists think it may link relationships to physical health.

Oxytocin as a Drug? Not So Fast

If oxytocin helps bonding, could an oxytocin nasal spray treat loneliness or social problems? So far, the evidence is disappointing. An early, famous finding that oxytocin spray makes people more trusting didn't hold up well when other researchers tried to repeat it (Nave et al., 2015). A large, careful trial in children and teens with autism found that daily oxytocin spray for six months worked no better than a placebo (Sikich et al., 2021).

Oxytocin's effects depend on the person and the situation. In one set of studies, it increased favoritism toward people's own group without making them kinder to outsiders (De Dreu et al., 2011). For now, the best way to get the benefits of oxytocin is the old-fashioned way: time with people who care about you.

Key Takeaways

- Hormones and behavior affect each other in both directions.
- Most sex differences in behavior are small averages with a lot of overlap.
- Oxytocin and vasopressin help build bonds, as prairie voles show.
- Supportive relationships calm the stress response and are linked to better health, but oxytocin spray isn't a proven treatment.

Check Your Understanding

1. About how much more likely were people with strong social relationships to be alive at follow-up?
2. What did the large autism trial find about oxytocin spray?
3. Where in the body is oxytocin made?

The answers are in the unit you just read.

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Unit 9.9: Module Wrap-Up

You made it through Module 9. Before you move on to emotion and stress, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Hormones are chemical messengers that affect only cells with the right receptors, and the influence runs both ways: hormones change behavior, and experiences like a stressful exam or becoming a father change hormones (9.1).
- Sex refers to biological traits, gender refers to the roles, expectations, and identities a culture builds around sex, and hormones have lasting organizational effects before birth and shorter-term activational effects later in life (9.2).
- A gene on the Y chromosome called SRY starts the processes that lead a fetus to develop testes, some people are born with intersex traits, and gender identity is a person's internal sense of being male, female, or something else (9.2).
- Most measured sex differences in thinking and personality are small, and the two groups overlap a lot, so knowing someone's sex tells you very little about that individual (9.2).
- Testosterone is more closely linked to competing for status than to violence, stress and heat can also make people quicker to snap, and biology doesn't remove choice (9.3).
- Parenting is shaped by experience and by hormones such as prolactin and oxytocin, the medial preoptic area of the hypothalamus is key for maternal care in rats, and men's testosterone tends to drop after they become fathers (9.4).
- Sexual arousal is a drive state that activates the brain's reward system, and because strong arousal changes decisions, it's best to decide about consent, boundaries, and protection ahead of time (9.5).
- Oxytocin and vasopressin help build social bonds, and prairie voles, which form lasting pair bonds, have more receptors for these hormones in the brain's reward areas (9.6).
- Under stress, the HPA axis releases cortisol, and many people "tend and befriend" by protecting loved ones and reaching out to others, which can calm the body's stress response (9.7).
- Strong relationships are linked to a longer life, but oxytocin nasal spray has not been shown to work as a treatment (9.8).

Why This Module Matters

Relationships are part of your biology. In many Valley families, raising kids is a group effort, with grandparents, tías and tíos, and older siblings helping to feed, watch, and teach the little ones, and scientists see that shared care as one reason humans can raise children who need care for so many years. When you're stressed, reaching out to someone you love can calm your body, even through a short phone call. And while hormones nudge behavior, they don't decide it: on a 108-degree afternoon or after a tough loss, you still choose how you respond.

Module 9 ideas in everyday life

Idea	Where you met it	Where you might see it
Hormones and behavior affect each other	9.1	Feeling bigger and more confident after a win, or stress hormones rising before an exam
Overlap between groups	9.2	Remembering that a stereotype about men or women tells you very little about the person in front of you
Heat and aggression	9.3	Tempers running short on a hot August afternoon, when shade, water, and a cool-down break help
Alloparenting	9.4	Grandparents, tías and tíos, and older siblings helping raise the little ones
Deciding ahead of time	9.5	Setting your boundaries while you're calm, like making a grocery list before you shop hungry
Tend and befriend	9.7	Calling someone you love after a hard day

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Who do you reach out to when something stressful or scary happens? How does your body feel after you talk to them?
2. Think about the people who helped raise you, or who help you raise children now. What did those relationships give you?
3. This module says hormones make some behaviors more or less likely but don't remove choice. Think of a time you felt a strong urge, like anger, and chose a different response. What helped?
4. Which idea about sex, gender, or relationships in this module surprised you most, and why?

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Unit 9.10: References

About This Module

This module was adapted and rewritten by Michael Miguel from his earlier Everything Love and Sex module, which drew on the Noba modules *Hormones & Behavior* by Randy J. Nelson and *Biochemistry of Love* by C. Sue Carter and Stephen W. Porges, and on the sexual arousal section of *Drive States* by Sudeep Bhatia and George Loewenstein, all licensed CC BY-NC-SA 4.0. Changes: rewritten in plain language for Coalinga College campus and Rising Scholars students; two introductions merged; sexual behavior moved in from Module 8; new diagrams; Central Valley examples added; facts checked and corrected. The web addresses below are for reference only; you don't need them to use this book.

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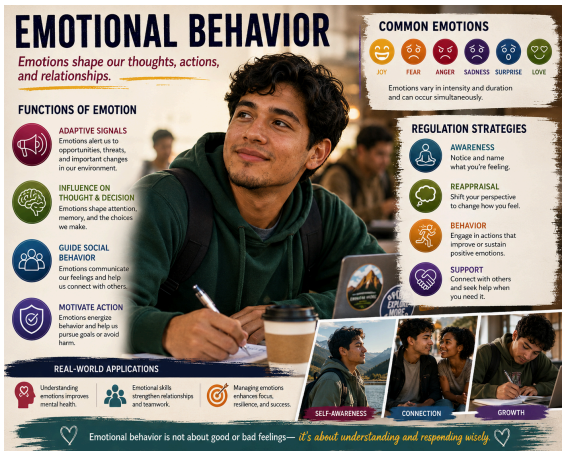
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MODULE 10: EMOTION AND STRESS



> **Image description:** An artistic poster titled "Emotional Behavior: Emotions shape our thoughts, actions, and relationships." A young man in a green hoodie smiles while writing in a notebook. Panels list six common emotions (joy, fear, anger, sadness, surprise, and love), four functions of emotion (adaptive signals, influence on thought and decision, guiding social behavior, and motivating action), and four regulation strategies (awareness, reappraisal, behavior, and support). Small photos are labeled self-awareness, connection, and growth. A banner reads, "Emotional behavior is not about good or bad feelings; it's about understanding and responding wisely." This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Your heart races before a test. Your face gets hot when someone disrespects you. You relax the moment a friend walks in. Emotions and stress aren't just feelings in your head; they are whole-body responses run by your brain, your hormones, and the people around you.

In this module, you'll see how the brain handles social life, which brain systems drive wanting, pleasure, fear, and anger, and how emotional experiences can reshape those systems. Then you'll follow the stress response from the brain to the bloodstream, see how long-term stress affects health, and learn which ways of coping actually help.

Learning Objectives

By the end of this module, you will be able to:

- Explain what social neuroscience studies and how quickly the brain sorts people into groups.
- Describe how affective neuroscientists study emotion, and compare the James–Lange, Cannon–Bard, and two-factor theories.
- Distinguish the brain systems for wanting and liking, and explain how they relate to addiction.
- Describe the fast and slow routes to fear and the role of the amygdala.
- Explain how emotional experiences can change the brain.
- Trace the HPA axis, describe Selye's General Adaptation Syndrome, and explain how chronic stress affects health.
- Compare problem-focused and emotion-focused coping, and identify factors that build resilience.

Unit 10.1: Social Neuroscience

Unit 10.2: Introduction to Affective Neuroscience

Unit 10.3: Wanting and Liking: The Brain's Reward System

Unit 10.4: Fear and Anger

Unit 10.5: Emotions Can Change the Brain
Unit 10.6: Stress and Health
Unit 10.7: Coping With Stress
Unit 10.8: Module Wrap-Up
Unit 10.9: References

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Unit 10.1: Social Neuroscience

Learning Objectives

By the end of this unit, you will be able to:

- Define social neuroscience.
- Explain social categorization and how it can feed stereotypes.
- Describe how the brain helps us understand other minds.

Humans are deeply social. We read faces, worry about what others think, and feel the sting of being left out. **Social neuroscience** studies how the brain and body support social thoughts, feelings, and behavior. The term appeared in the early 1990s (Cacioppo & Berntson, 1992), and the field grew quickly as tools like electroencephalography (EEG) and functional MRI (fMRI) (Module 2) let researchers watch the brain during social tasks.

Social neuroscience works in both directions. Biology shapes how we respond to other people, and social experiences, like support or rejection, change the body in return.

Sorting People Into Groups

Your brain sorts people into categories such as age, gender, and race almost instantly. This **social categorization** is a mental shortcut that saves effort, but it can also feed stereotypes and snap judgments. In one EEG study, the brain responded differently to faces of different races and genders within about 100 to 200 milliseconds, even when people were focused on another task (Ito & Urland, 2003). Noticing a category is automatic; what we do with it next is not.

Understanding Other Minds

When you try to figure out what someone else is thinking or feeling, an area in the middle of the frontal lobes, the medial prefrontal cortex, becomes more active. Part of it responds more when people think about others who seem similar to themselves (Mitchell et al., 2006), which may be one reason empathy comes more easily with people we see as “like us.” Deliberately imagining another person’s point of view can widen that circle.

From a Peer

“I used to think bias only meant judging someone on purpose. Knowing my brain sorts people automatically makes me slow down and check my first impression.”

Check Your Understanding

1. What does social neuroscience study?
2. What is social categorization, and why can it be a problem?
3. Which brain area is active when you think about other people’s thoughts and feelings?

The answers are in the unit you just read.

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Unit 10.2: Introduction to Affective Neuroscience

Learning Objectives

By the end of this unit, you will be able to:

- Define affective neuroscience and describe the parts of an emotion.
- Compare the James–Lange, Cannon–Bard, and two-factor theories.
- Explain how emotions depend on brain networks, and how culture shapes emotional expression.

Fear helps you escape danger. Joy pulls you toward people and activities that are good for you. Sadness signals loss. **Affective neuroscience** is the study of how the brain produces emotions. An emotion is more than a feeling: it includes changes in brain activity, body physiology, facial expression, and readiness to act. Fear, for example, speeds up your heart, sharpens your attention, and prepares your muscles to move.

How Emotion Is Studied

Researchers use several tools you met in Module 2. Electroencephalography (EEG) shows when the brain responds to an emotional picture or sound, down to the millisecond. fMRI shows where activity increases. Lesion studies, in people with brain injuries and in animals, show what changes when an area is damaged. Drug studies show which chemical messengers, like dopamine or opioids, are involved.

Animal research is especially important here because the core emotional systems are old in evolutionary terms and shared by mammals. A rat, a dog, and a person all have an amygdala and a hypothalamus that respond to threats in similar ways. Human emotions are richer, because we also think about our feelings, put them into words, and shape them through culture, but the basic circuits are similar.

Where Do Feelings Come From?

Early theories argued about the order of events. The **James–Lange theory** says the body reacts first and the feeling follows: you feel afraid because you notice your heart racing (James, 1884). The **Cannon–Bard theory** says the brain triggers the body's reaction and the feeling at the same time (Cannon, 1927).

The **two-factor theory** adds thinking: you notice arousal, then label it from the situation, so a pounding heart can feel like fear in a dark parking lot or excitement at a concert (Schachter & Singer, 1962). Today's research keeps a piece of each: body signals, brain activity, and how we interpret the situation all shape what we feel.

Culture shapes what we show on the outside, too. In one study, European American and Hmong American adults relived happy and proud moments from their lives. Both groups reported feeling just as happy and proud, and their heart rates and other body responses were similar. But the European Americans smiled more often and more intensely (Tsai et al., 2002, as cited in Tsai, n.d.). Cultures have different **display rules**, unwritten rules about which emotions are okay to show in a given situation (Tsai, n.d.). The same feeling inside can look different on the outside.

Networks, Not Single Spots

Researchers such as Jaak Panksepp (1998) and Kent Berridge showed that each emotion depends on a network of brain areas working together, not on one "emotion center." Key players include the amygdala, the nucleus accumbens, the hypothalamus, and the prefrontal cortex. These networks evolved because they help animals survive: they push us to seek food and safety, avoid danger, care for young, and stay connected to others.

In Plain Words

Emotions aren't a weakness or a glitch. They are the brain's built-in guidance system, telling you what matters right now and getting your body ready to act on it.

From a Peer

"I used to think emotions were something I should just control better. Seeing them as brain systems made me more patient with myself and with other people."

Check Your Understanding

1. What is affective neuroscience?
2. Name two tools researchers use to study emotion in the brain.
3. According to the James–Lange theory, which comes first: the body's reaction or the feeling?
4. Why are animal studies useful for understanding human emotion?

The answers are in the unit you just read.

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Unit 10.3: Wanting and Liking: The Brain's Reward System

Learning Objectives

By the end of this unit, you will be able to:

- Distinguish the wanting system from the liking system.
- Describe the roles of dopamine and the nucleus accumbens.
- Explain how wanting and liking can split apart in addiction.

Why do you keep checking your phone, even when nothing on it makes you happy? Affective neuroscience has a surprising answer: wanting something and liking it are handled by different brain systems.

Wanting: The Desire System

The **wanting system** (also called the desire or reward-seeking system) pushes you to go after things like food, safety, success, and companionship. It runs largely on **dopamine** pathways that reach the **nucleus accumbens** and the frontal cortex, along with areas such as the lateral hypothalamus and amygdala. When this system is active, people feel energized, curious, and focused on a goal. When it is underactive, motivation drops, which is one feature of depression (Module 14).

In a classic study, rats with electrodes in certain brain areas pressed a lever over and over to get brief electrical stimulation there (Olds & Milner, 1954). This showed how strongly reward circuits can drive behavior.

Liking: The Pleasure System

The **liking system** produces the actual pleasure of a reward. It depends on small "hotspots" in the nucleus accumbens and the ventral pallidum that use the brain's own opioids and endocannabinoids, not mainly dopamine (Berridge & Kringelbach, 2015). The orbitofrontal cortex, just above the eyes, helps judge how pleasant a taste, smell, or face is.

When Wanting and Liking Split Apart

Usually, we want what we like. But with repeated drug use, the wanting system can become oversensitive, while the pleasure from the drug fades. A person may crave a drug intensely even though using it no longer feels good (Berridge & Robinson, 2016). Drugs such as cocaine and amphetamines boost dopamine directly, and over time natural rewards can feel less satisfying. This is one reason addiction is understood as a brain condition, not a lack of willpower (Module 13).

In Plain Words

Wanting is the "go get it" signal. Liking is the "this feels good" signal. Addiction can turn up the first while the second fades.

From a Peer

"The wanting-versus-liking idea finally explained why I kept scrolling at night even when it made me feel worse."

Check Your Understanding

1. Which neurotransmitter is most tied to wanting?
2. Which brain chemicals are tied to liking?

3. How can wanting and liking come apart in addiction?

The answers are in the unit you just read.

This page titled Unit 10.3: Wanting and Liking: The Brain's Reward System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Michael Miguel.

Unit 10.4: Fear and Anger

Learning Objectives

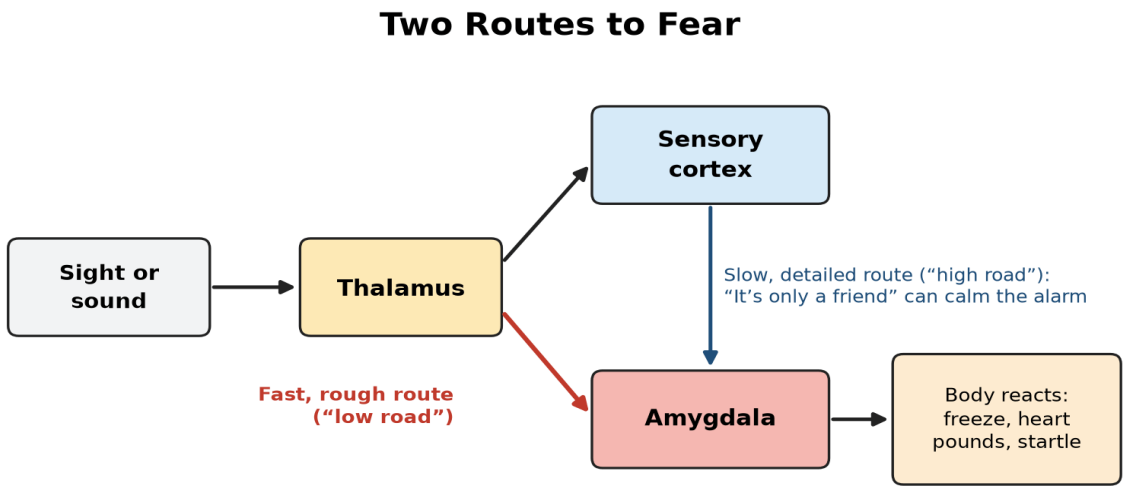
By the end of this unit, you will be able to:

- Describe the fast and slow routes to fear through the thalamus and amygdala.
- Describe the freeze, flight, and fight responses and the role of the periaqueductal gray (PAG).
- Explain how social rejection can hurt like physical pain.

You're walking home after dark and hear fast footsteps behind you. Before you even think, your heart pounds, your muscles tighten, and you freeze for a split second. Then you recognize your friend's voice calling your name. Fear is one of the brain's most important survival systems, and it is built to act first and ask questions later.

Two Routes to Fear

The **amygdala**, a small almond-shaped structure deep in the temporal lobe, is central to detecting threats. Sights and sounds reach it by two routes (LeDoux, 1996). A fast, rough route goes straight from the **thalamus** to the amygdala, so the body can react in a fraction of a second. A slower route goes through the sensory cortex, which works out what the stimulus really is. If the cortex decides "it's only a friend," the alarm calms down. The diagram below shows these two routes to fear.



> **Image description:** A flow diagram. A sight or sound goes to the thalamus. From there, a fast, rough route (the "low road," in red) goes straight to the amygdala. A slower, detailed route (the "high road," in blue) goes from the thalamus to the sensory cortex and then down to the amygdala; a note says this route can decide "It's only a friend" and calm the alarm. The amygdala then triggers the body's reaction: freezing, a pounding heart, and startle.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Once activated, the amygdala signals the hypothalamus, which turns on the sympathetic nervous system and stress hormones, and the **periaqueductal gray (PAG)** in the midbrain, which helps produce freezing, fleeing, or defensive fighting:

- **Freeze:** a brief stop that helps avoid being noticed while the brain sizes up the threat.
- **Flight:** escape, with a faster heart rate and breathing to fuel the muscles.
- **Fight:** defensive aggression when escape isn't possible.

Anti-anxiety drugs called benzodiazepines calm this circuit by boosting GABA (gamma-aminobutyric acid), the brain's main "slow down" messenger (Module 13).

Anger, Bonding, and Social Pain

Other emotions use overlapping circuits. Anger, or rage, involves parts of the amygdala, the hypothalamus, and the PAG, and often appears when goals are blocked or when we are hurt (Panksepp, 1998). Hormones such as testosterone and vasopressin can make aggressive responses more likely. Caregiving and bonding rely on oxytocin (Module 9) and the brain's own opioids (Unit 6.10). Being left out activates some of the same brain areas as physical pain (Eisenberger et al., 2003), which may help explain why rejection can hurt so much.

In Plain Words

Your amygdala works like a smoke alarm: it would rather go off for burnt toast than miss a real fire. False alarms are the price of a fast warning system.

From a Peer

"Learning that my body reacts before I can think helped me stop blaming myself for jumping at loud noises. Now I breathe and let the slow route catch up."

Check Your Understanding

1. Which brain structure is central to detecting threats?
2. What is the difference between the fast and slow routes to fear?
3. What are the three defensive responses to a threat?

The answers are in the unit you just read.

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Unit 10.5: Emotions Can Change the Brain

Learning Objectives

By the end of this unit, you will be able to:

- Explain how emotional experiences can change the brain.
- Describe how stress can strengthen fear pathways and how support and therapy can strengthen calmer ones.

The brain is not fixed. It keeps changing with experience, a property called neuroplasticity (Module 4). A common summary is "neurons that fire together wire together": thoughts, feelings, and actions that repeat strengthen the connections behind them.

Emotional experiences are no exception. In rats, part of the nucleus accumbens can produce either eager, reward-seeking behavior or fearful behavior. In a stressful setting with bright lights and loud noise, more of that area switched to producing fear; in a calm, familiar setting, more of it produced desire (Reynolds & Berridge, 2008). The same brain tissue was "retuned" by its surroundings.

This helps explain why long-term stress or trauma can strengthen fear and anxiety pathways, making alarms easier to set off. It also explains why recovery is possible: therapy, supportive relationships, safe experiences, and healthy habits can strengthen calmer pathways. Even the amygdala isn't only a "fear center"; parts of it respond to rewards and to uncertainty. Emotions come from flexible networks that keep adjusting to experience.

From a Peer

"Knowing the brain can rewire gave me hope. The way I react now doesn't have to be the way I react forever."

Check Your Understanding

1. What is neuroplasticity?
2. How did a stressful setting change the rats' nucleus accumbens?
3. Name two experiences that can strengthen calmer emotional pathways.

The answers are in the unit you just read.

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Unit 10.6: Stress and Health

Learning Objectives

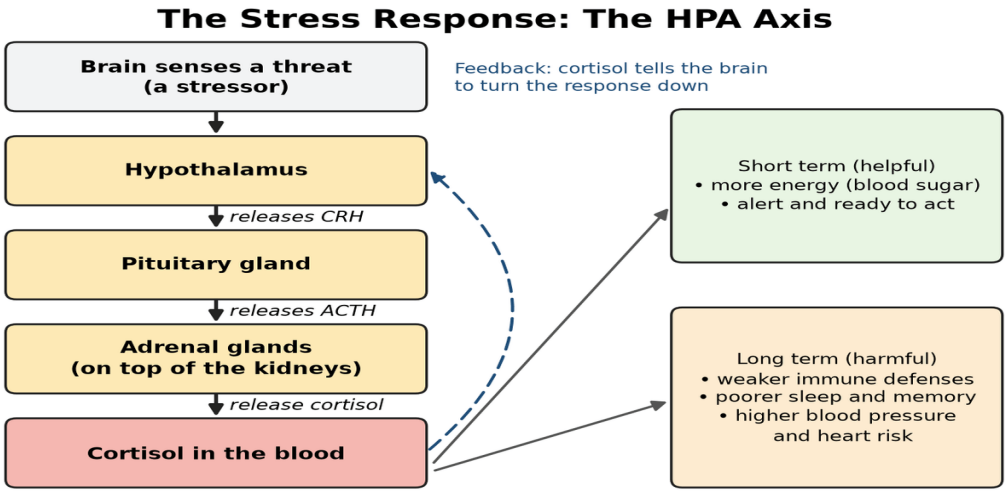
By the end of this unit, you will be able to:

- Define a stressor and describe the fight-or-flight response and the HPA axis.
- Describe the stages of the General Adaptation Syndrome.
- Explain allostatic load and the biopsychosocial model of stress.

A **stressor** is anything that threatens or challenges your well-being, from an injury to a deadline to a fight with someone you love. Stress is the body's response to it. In the short term, that response helps you survive. When it never shuts off, it wears the body down (Sapolsky, 2004).

The Stress Response

Stress uses two systems. The first is fast: the sympathetic nervous system triggers the **fight-or-flight response**, described by Walter Cannon (1932), releasing epinephrine (adrenaline) and norepinephrine within seconds. The second is slower: the **HPA axis** (hypothalamus–pituitary–adrenal axis). The hypothalamus releases corticotropin-releasing hormone (CRH), which signals the pituitary gland to release adrenocorticotropic hormone (ACTH), which signals the adrenal glands to release **cortisol**. Cortisol raises blood sugar for energy, and it also signals the brain to turn the response down once the threat passes. The flow chart below shows each step.

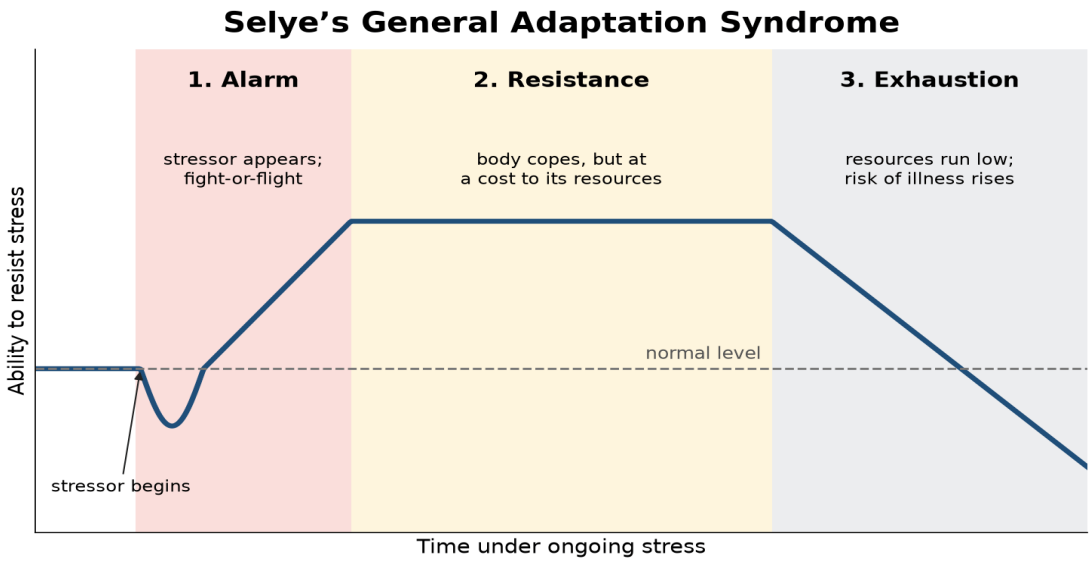


> **Image description:** A top-to-bottom flow chart. The brain senses a threat. The hypothalamus releases CRH, which signals the pituitary gland. The pituitary releases ACTH, which signals the adrenal glands on top of the kidneys. The adrenal glands release cortisol into the blood. A dashed feedback arrow shows cortisol telling the brain to turn the response down. Two boxes list cortisol's effects. Short term, helpful: more energy from blood sugar, and feeling alert and ready to act. Long term, harmful: weaker immune defenses, poorer sleep and memory, and higher blood pressure and heart risk.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Hans Selye (1936) noticed that animals exposed to many different long-lasting stressors got sick in similar ways. His **General Adaptation Syndrome** describes three stages: alarm (the body reacts), resistance (the body copes, at a cost), and exhaustion

(resources run low and illness becomes more likely). The graph below shows the three stages.



> **Image description:** A line graph of the ability to resist stress over time under ongoing stress, with a dashed line marking the normal level. When the stressor begins, the line dips briefly below normal in stage 1, alarm (fight-or-flight), then climbs above normal. In stage 2, resistance, it stays high as the body copes at a cost to its resources. In stage 3, exhaustion, it falls below normal as resources run low and the risk of illness rises. The shape is a simplified model, not measured data.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

How Stress Gets Under the Skin

Some of the strongest stressors are social. Tasks that combine being judged with having little control, like giving a speech to critical evaluators, cause the biggest cortisol rises (Dickerson & Kemeny, 2004; Dickerson et al., 2008). Over time, stress weakens immune defenses: in one study, volunteers exposed to a cold virus were more likely to get sick if they were under more stress (Cohen et al., 1991). The total wear and tear from years of stress responses is called **allostatic load** (McEwen, 1998), and it is linked to high blood pressure, heart disease, poor sleep, and depression.

Health psychologists use the **biopsychosocial model**: health depends on biological factors (genes, hormones), psychological factors (thoughts, emotions, coping), and social factors (relationships, money, access to care) together. Strong relationships are one of the most protective factors; across many studies, people with stronger social ties were about 50% more likely to survive over the study period (Holt-Lunstad et al., 2010).

Close to Home

Heat waves over 105°, the long hours of harvest season, and weeks of wildfire smoke are all stressors that hit the body directly. Knowing that, plan cool rest breaks, check air-quality alerts, drink water, and lean on the people around you. Your stress response is working; it needs a chance to shut off.

Check Your Understanding

1. Name the three parts of the HPA axis, in order.
2. Which hormone do the adrenal glands release in the HPA axis?
3. What are the three stages of Selye's General Adaptation Syndrome?
4. What is allostatic load?

> *The answers are in the unit you just read.*

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Unit 10.7: Coping With Stress

Learning Objectives

By the end of this unit, you will be able to:

- Compare problem-focused and emotion-focused coping.
- Explain how control, self-efficacy, and outlook affect stress.
- Give examples of tools that help, such as relaxation, mindfulness, and biofeedback.

Stress can't be avoided, but how you respond to it shapes both mental and physical health. **Coping** means the thoughts and actions people use to manage stress. Psychologists describe two main types (Lazarus & Folkman, 1984):

- **Problem-focused coping** changes the stressor itself: making a study plan, asking for help, or working out a budget. It works best when you have some control.
- **Emotion-focused coping** changes how you feel about the stressor: talking to a friend, exercising, praying, journaling, or breathing slowly. It is especially useful when the situation can't be changed.

Most people do best combining both, choosing the type that fits the moment.

Control, Confidence, and Outlook

Feeling some control matters. In a nursing-home study, residents who were given small choices and a plant to care for became happier and more active than residents who weren't (Langer & Rodin, 1976), and a small follow-up found fewer deaths in that group (Rodin & Langer, 1977). Closely related is **self-efficacy**, the belief that you can handle a challenge, which predicts better coping and healthier habits.

Personality plays a role too. The **Type A behavior pattern**, a competitive, impatient, and hostile style, was first linked to heart disease by Friedman and Rosenman (1959). Later research found that hostility and anger are the parts that matter most (Chida & Steptoe, 2009). On the positive side, optimism and positive emotions are linked to better health (Pressman & Cohen, 2005); people with a more positive emotional style even caught fewer colds after exposure to a virus (Cohen et al., 2003).

Tools That Help

- **Relaxation:** slow breathing and tensing and relaxing muscle groups calm the sympathetic nervous system.
- **Mindfulness:** calm attention to the present moment reliably reduces stress (Khoury et al., 2015).
- **Biofeedback:** sensors show heart rate or muscle tension so you can learn to lower them.
- **Exercise, sleep, and connection:** regular movement, enough sleep (Module 7), and supportive people all make stress easier to recover from.

When Your Schedule Isn't Yours

Many students have little say over when they work, sleep, or eat, whether because of shift work, caring for family, or a schedule set by an institution. When you can't change the stressor, emotion-focused coping and small pockets of control help: choose how you use ten free minutes, keep one steady routine like a walk or a breathing practice, and stay in touch with people who steady you. **Resilience**, the ability to recover from adversity, is built from small habits like these.

From a Peer

"I used to think coping meant staying calm no matter what. Now I ask: can I fix this, or do I need to take care of myself while I get through it?"

Check Your Understanding

1. What is the difference between problem-focused and emotion-focused coping?
2. What is self-efficacy?
3. Which part of the Type A pattern is most tied to heart disease?
4. Name two stress-management tools.

The answers are in the unit you just read.

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Unit 10.8: Module Wrap-Up

You made it through Module 10. Before you move on to learning and memory, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Social neuroscience studies how the brain and body support social life, and your brain sorts people into groups within a fraction of a second, but what you do with that first impression is not automatic (10.1).
- Affective neuroscience studies how the brain produces emotions, which include changes in brain activity, body physiology, facial expression, and readiness to act, and each emotion depends on a network of brain areas rather than one "emotion center" (10.2).
- The James–Lange, Cannon–Bard, and two-factor theories disagree about the order of body reactions, feelings, and thoughts, and today's research keeps a piece of each (10.2).
- Culture shapes which emotions people show through display rules, so the same feeling inside can look different on the outside (10.2).
- Wanting runs largely on dopamine, while liking depends on the brain's own opioids and endocannabinoids, and in addiction the wanting system can grow stronger even as the pleasure fades (10.3).
- The amygdala detects threats through a fast route straight from the thalamus and a slower route through the sensory cortex, which can calm the alarm once it works out what is really there (10.4).
- Emotional experiences can retune the brain, so long-term stress can strengthen fear pathways, while therapy, supportive relationships, and safe experiences can strengthen calmer ones (10.5).
- Stress turns on a fast fight-or-flight response and the slower HPA axis, which releases cortisol, and Selye's General Adaptation Syndrome describes the alarm, resistance, and exhaustion stages of long-lasting stress (10.6).
- The wear and tear from years of stress, called allostatic load, is linked to high blood pressure, heart disease, poor sleep, and depression, and the biopsychosocial model shows how biology, mind, and social life shape health together (10.6).
- Problem-focused coping changes the stressor, emotion-focused coping changes how you feel about it, and a sense of control, self-efficacy, and small daily habits help build resilience (10.7).

Why This Module Matters

Stress is part of life in the Valley: heat waves over 105°, the long hours of harvest season, and weeks of wildfire smoke all hit the body directly. Knowing how your stress response works can help you plan cool rest breaks, check air-quality alerts, and lean on the people around you, so your body gets a chance to shut the alarm off. And when you can't change the stressor, whether because of shift work, caring for family, or a schedule set by someone else, emotion-focused coping and small pockets of control still help.

Module 10 ideas in everyday life

Idea	Where you met it	Where you might see it
Two-factor theory	10.2	A pounding heart feeling like fear in a dark parking lot but like excitement at a concert
Wanting vs. liking	10.3	Scrolling your phone late at night even when it makes you feel worse
Two routes to fear	10.4	Freezing at footsteps behind you, then relaxing when you hear a friend's voice
Social pain	10.4	Feeling hurt when you're left out
Problem-focused coping	10.7	Making a study plan, asking for help, or working out a budget
Emotion-focused coping	10.7	Talking to a friend, praying, journaling, or slow breathing when you can't change the situation

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. Think of a recent time you felt a strong emotion. What did you notice first: the feeling, your body's reaction, or your thoughts about the situation?
2. What are the biggest sources of stress in your life right now? For each one, would problem-focused coping, emotion-focused coping, or a mix fit best?
3. Is there something you keep "wanting" even though you don't really "like" it anymore? What might help you notice that pattern?
4. What small habit helps you recover after a stressful day? How could you make room for it more often?

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Unit 10.9: References

About This Module

This module was adapted and rewritten by Michael Miguel from his earlier Emotional Behavior module, which drew on the Noba modules Social Neuroscience by Tiffany A. Ito and Jennifer T. Kubota, Affective Neuroscience by Eddie Harmon-Jones and Cindy Harmon-Jones (as adapted in Chapter 10 of *Biological Psychology* by Michael J. Hove and Steven A. Martinez, ROTEL Project), and The Healthy Life by Emily Hooker and Sarah Pressman, all licensed CC BY-NC-SA 4.0. Changes: condensed and reorganized from 15 pages to 7 units, plain language for Coalinga College campus and Rising Scholars students, Central Valley examples, review questions, corrected facts, and new diagrams. Terms are defined in the book Glossary.

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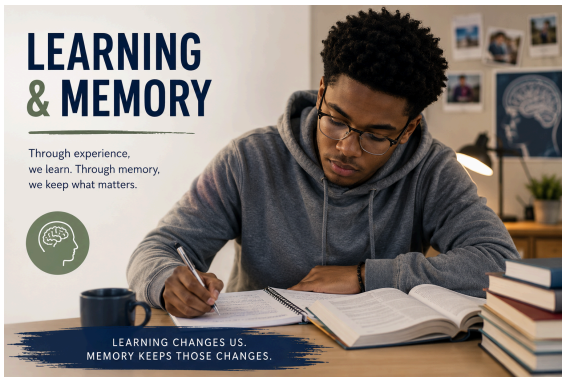
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MODULE 11: LEARNING AND MEMORY



> **Image description:** An artistic poster titled “Learning & Memory.” A young man in glasses and a gray hoodie writes in a notebook next to an open textbook, a mug, and a stack of books, with photos and a brain drawing pinned to the wall behind him. Text reads, “Through experience, we learn. Through memory, we keep what matters,” and a banner reads, “Learning changes us. Memory keeps those changes.” This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Everything you know, from your home address to how to ride a bike to the smell that reminds you of a grandparent’s kitchen, is stored in your brain because of learning and memory. They are also why a song can lift your mood, why one bad meal can ruin a food for years, and why the night-before cram session rarely sticks.

In this module, you’ll learn the main types of memory, how memories are encoded, stored, and retrieved, and which brain areas make that possible. Then you’ll see how we learn through classical and operant conditioning, why we forget, what happens in Alzheimer’s disease, and which study methods the research says actually work.

Learning Objectives

By the end of this module, you will be able to:

- Distinguish sensory, short-term (working), and long-term memory, and explicit and implicit memory.
- Describe encoding, storage, and retrieval, and explain why memory is reconstructive.
- Identify the brain areas involved in memory, using the case of H.M.
- Explain classical conditioning and its real-world effects, including extinction and renewal.
- Explain operant conditioning, including reinforcement, punishment, and habits.
- Describe the main causes of forgetting and the brain changes in Alzheimer’s disease.
- Apply research-based study strategies such as retrieval practice and spacing.

Unit 11.1: Introduction to Learning and Memory
Unit 11.2: Types of Memory
Unit 11.3: Encoding
Unit 11.4: Storage and the Brain
Unit 11.5: Retrieval
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Unit 11.1: Introduction to Learning and Memory

Learning Objectives

By the end of this unit, you will be able to:

- Define learning and memory.
- Describe the three steps of memory: encoding, storage, and retrieval.

In 2013, memory athlete Simon Reinhard sat before an audience at Washington University in St. Louis and memorized strings of random digits flashed on a screen: first 10, then 20, then 30, then 50, without a single error. His record is 240 digits in a row. Yet the normal memory span for adults is only about 7 digits (McDermott & Roediger, n.d.). He doesn't have a "photographic memory." He uses trained strategies, like turning numbers into vivid images placed along a familiar route, that anyone can learn.

Learning is a lasting change in behavior or knowledge that comes from experience. **Memory** is the ability to keep and use what was learned. Every memory passes through three steps:

- **Encoding:** taking in information and connecting it to what you already know.
- **Storage:** keeping that information over time.
- **Retrieval:** bringing it back when you need it.

If you forget someone's name a week after meeting them, the problem could be at any step: you may not have paid attention (encoding), the memory may have faded (storage), or it may be there but out of reach (retrieval). This module also covers conditioning, the simplest forms of learning, which you share with nearly every animal. Each step depends on physical changes in the brain, as connections between neurons strengthen or weaken (Modules 3 and 4).

From a Peer

"I always said I had a bad memory. Learning that memory is a set of skills, not a fixed trait, changed how I study."

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Unit 11.2: Types of Memory

Learning Objectives

By the end of this unit, you will be able to:

- Compare sensory, short-term, and long-term memory, and describe working memory and chunking.
- Distinguish explicit memory (episodic and semantic) from implicit memory (procedural).

Memory isn't one thing. A classic model divides it into three stores that information moves through (Atkinson & Shiffrin, 1968):

- **Sensory memory** holds a brief, detailed copy of what you just saw or heard, for less than a second for sights and a few seconds for sounds.
- **Short-term memory** holds what you're thinking about right now, for about 15 to 30 seconds unless you rehearse it.
- **Long-term memory** holds information for days to a lifetime, with no known limit.

Working Memory

Today, short-term memory is usually called **working memory**, because it doesn't just hold information; it works with it, as when you figure a tip in your head (Baddeley & Hitch, 1974). Its capacity is small. George Miller (1956) famously estimated "seven, plus or minus two" items, but later research suggests most adults can actively hold only about four meaningful chunks (Cowan, 2001). **Chunking**, grouping items into meaningful units, stretches that limit: 5-5-9-2-0-1-4 is seven digits, but 559 (the Fresno area code) plus 2014 is just two chunks.

In Plain Words

Working memory is like a sticky note: handy, but small, and it gets thrown away fast unless you copy what matters into long-term memory.

Kinds of Long-Term Memory

Explicit memory (also called declarative memory) is memory you can consciously recall and put into words. It includes **episodic memory**, your memory for events you lived, like your first day of college, and **semantic memory**, your general knowledge, like the fact that Sacramento is California's capital.

Implicit memory (nondeclarative memory) shows up in what you do rather than what you can say. It includes **procedural memory** for skills and habits, like typing or driving a stick shift, along with priming (Module 7) and classical conditioning (Unit 11.7). You may not remember learning these, but they still guide your behavior.

Check Your Understanding

1. What are the three memory stores in the Atkinson–Shiffrin model?
2. About how many chunks can working memory hold?
3. What is the difference between episodic and semantic memory?
4. Give an example of procedural memory.

The answers are in the unit you just read.

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Unit 11.3: Encoding

Learning Objectives

By the end of this unit, you will be able to:

- Describe what makes encoding stronger.
- Explain how false memories form and why flashbulb memories aren't more accurate.

Every memory begins with **encoding**, turning an experience into a form the brain can store. Encoding is not a video recording. Your brain is selective: walking across campus, you notice a friend's face but not the color of every car. What isn't attended to usually isn't encoded at all.

What Makes Encoding Stronger

- **Meaning:** thinking about what information means, and connecting it to what you already know, produces much better memory than focusing on how it looks or sounds (Craik & Lockhart, 1972). This is often called deep processing.
- **Distinctiveness:** unusual events stand out. A goat wandering past the library would be remembered for years.
- **Emotion:** emotional events are encoded more strongly, partly because the amygdala boosts activity in memory areas (Module 10).
- **Recoding:** we reorganize information to make it easier to keep, as with the acronym ROY G BIV for the colors of the rainbow.

When Encoding Adds Things That Weren't There

Because we encode meaning, not exact copies, memory can fill in gaps. In a classic experiment, people heard lists of related words like *door, glass, pane, shade, ledge, sill*. Many later "remembered" hearing *window*, which was never on the list, and felt confident about it (Roediger & McDermott, 1995). This is a **false memory**: remembering something that didn't happen.

Strong emotion doesn't guarantee accuracy either. **Flashbulb memories** are vivid memories of where you were when you heard shocking news (Brown & Kulik, 1977). When researchers tested students the day after the September 11, 2001, attacks and again months later, the flashbulb memories changed as much as everyday memories did, but people stayed much more confident in them (Talarico & Rubin, 2003).

From a Peer

"I was sure I remembered exactly where I was when I got some bad news. My sister remembers it completely differently, and now I'm not sure which of us is right."

Check Your Understanding

1. What is encoding?
2. Why does thinking about meaning improve memory?
3. What is a flashbulb memory, and is it more accurate than other memories?

The answers are in the unit you just read.

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Unit 11.4: Storage and the Brain

Learning Objectives

By the end of this unit, you will be able to:

- Define consolidation and engram.
- Describe what the case of H.M. showed, and distinguish anterograde from retrograde amnesia.
- Identify brain areas involved in different kinds of memory.

When you learn something, your brain physically changes. The lasting trace of a memory is called an **engram**. At first a new memory is fragile; over hours to years it becomes more stable through **consolidation**. Consolidation happens at the level of synapses, as connections between neurons strengthen through long-term potentiation (Module 4), and at the level of brain systems, as memories come to depend less on the hippocampus and more on the cortex (McGaugh, 2000). Sleep, especially deep sleep, helps this process (Module 7).

The Case of H.M.

The most famous case in memory research is Henry Molaison, known for decades as H.M. To stop his severe seizures, surgeons in 1953 removed the medial parts of both of his temporal lobes, including much of the **hippocampus**. His seizures improved, but he could no longer form new explicit memories (Scoville & Milner, 1957).

He could talk with you for an hour and not remember meeting you minutes later. This is **anterograde amnesia**, the inability to form new memories after an injury. He also had some **retrograde amnesia**, loss of memories from before the surgery, mostly for the years just before it; his childhood memories were intact.

Yet H.M. could still learn skills. Asked to trace a star while watching his hand only in a mirror, he improved day after day, even though each day he said he had never done the task before. His case showed that different types of memory depend on different brain systems. The tree diagram below shows the types of long-term memory and the brain areas that support each one.

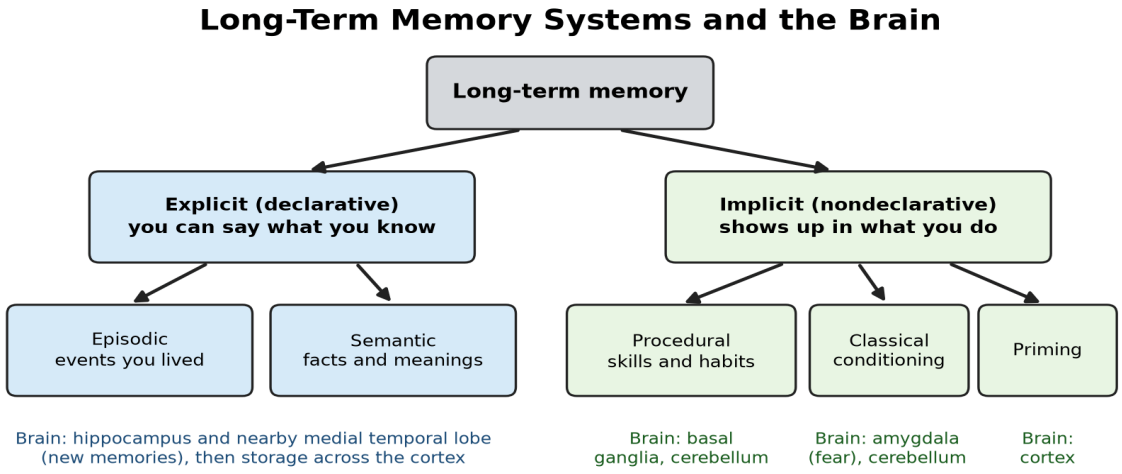


Image description: A tree diagram. Long-term memory splits into explicit (declarative) memory, which you can say you know, and implicit (nondeclarative) memory, which shows up in what you do. Explicit memory splits into episodic memory (events you lived) and semantic memory (facts and meanings); both depend on the hippocampus and nearby medial temporal lobe for new memories, then on storage across the cortex. Implicit memory splits

> into procedural memory (skills and habits), supported by the basal ganglia and cerebellum; classical conditioning, supported by the amygdala (for fear) and cerebellum; and priming, supported by the cortex.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

- The **hippocampus** and nearby medial temporal lobe form new explicit memories and link details into an event.
- The **amygdala** strengthens emotional memories and is key for fear conditioning.
- The **basal ganglia** support habits and procedural skills.
- The **cerebellum** supports timed motor skills and some simple conditioning.
- The **prefrontal cortex** supports working memory and organizing what you learn.

Check Your Understanding

1. What is consolidation?
2. What surgery did H.M. have, and what kind of amnesia did it cause?
3. Which brain structure is most important for forming new explicit memories?
4. What could H.M. still learn?

The answers are in the unit you just read.

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Unit 11.5: Retrieval

Learning Objectives

By the end of this unit, you will be able to:

- Explain how retrieval cues and the encoding specificity principle work.
- Describe the testing effect and the misinformation effect.

A memory is only useful if you can get it back. **Retrieval** is bringing stored information back into awareness. Much of what we store is *available* (still in memory) but not always *accessible* (reachable right now). In one study, people who couldn't recall words from a list remembered many more when given category hints like "animals" (Tulving & Pearlstone, 1966). That's also why recognizing an answer on a multiple-choice test is easier than recalling it from scratch.

Cues and Context

Retrieval cues are reminders that help bring a memory back. According to the **encoding specificity principle**, cues work best when they match the conditions present during learning (Tulving & Thomson, 1973). Scuba divers who learned words underwater recalled them better underwater, and words learned on land were better recalled on land (Godden & Baddeley, 1975). A song, a smell, or a place can bring back a memory for the same reason.

Retrieval Changes Memory

Retrieving a memory makes it stronger. Students who practiced recalling a passage remembered much more a week later than students who spent the same time rereading it (Roediger & Karpicke, 2006). This **testing effect**, also called retrieval practice, is one of the most useful findings in learning research.

But each retrieval is also a reconstruction. Bartlett (1932) found that when British students retold an unfamiliar Native American folk tale, they changed details to fit their own culture.

In another study, people watched a film of a car crash. Those asked how fast the cars were going when they "smashed into" each other gave higher speed estimates, and a week later, 32% claimed to have seen broken glass, compared with 14% of those asked about cars that "hit" each other (Loftus & Palmer, 1974). There was no broken glass. This is the **misinformation effect**: information received after an event changes the memory of it. It is a major reason eyewitness memory can be wrong.

In Plain Words

Remembering is less like opening a saved video and more like retelling a story from notes. Each retelling can add or change a detail.

From a Peer

"Quizzing myself with flashcards felt harder than rereading, but my test scores went up. Now I know why."

Check Your Understanding

1. What is the difference between available and accessible memories?
2. What does the encoding specificity principle say?
3. What is the testing effect?

4. What is the misinformation effect?

The answers are in the unit you just read.

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Unit 11.6: Introduction to Conditioning

Learning Objectives

By the end of this unit, you will be able to:

- Define classical conditioning and operant conditioning.
- Explain Thorndike's law of effect.

Ivan Pavlov won a Nobel Prize in 1904 for his research on digestion, but he is remembered for something he noticed along the way: his dogs began to drool before food arrived, at the sight of the assistant who fed them or at sounds that came before feeding. Pavlov had discovered **classical conditioning**, learning that one stimulus predicts another (Pavlov, 1927). After a sound such as a metronome or tone was paired with food many times, the sound alone made the dogs salivate.

Classical conditioning is everywhere. It explains why a certain song brings back a person, why the smell of a food you once got sick on can turn your stomach, and why the sound of your morning alarm can make you tense up even on a day off.

Close to Home

On a Valley jobsite or campus, the lunch truck pulls up and honks. After a few weeks, people's stomachs start growling at the horn alone, before they smell any food. That's Pavlov in real life.

Learning From Consequences

A second kind of learning depends on what happens after you act. Edward Thorndike (1898) put cats in "puzzle boxes" and found that they escaped faster and faster as actions that opened the door were repeated and useless ones dropped away. His **law of effect** says that behaviors followed by satisfying results become more likely, and behaviors followed by unpleasant results become less likely. B. F. Skinner (1938) later called this **operant conditioning** (also called instrumental conditioning), because the animal "operates" on its environment.

The difference: classical conditioning links two stimuli and mostly shapes automatic reactions, like drooling, fear, or nausea. Operant conditioning links a behavior with its consequence and mostly shapes voluntary actions, like studying, working, or checking your phone. Both depend on the brain's ability to detect what predicts what.

Check Your Understanding

1. What did Pavlov discover about his dogs?
2. What is the law of effect?
3. How is operant conditioning different from classical conditioning?

The answers are in the unit you just read.

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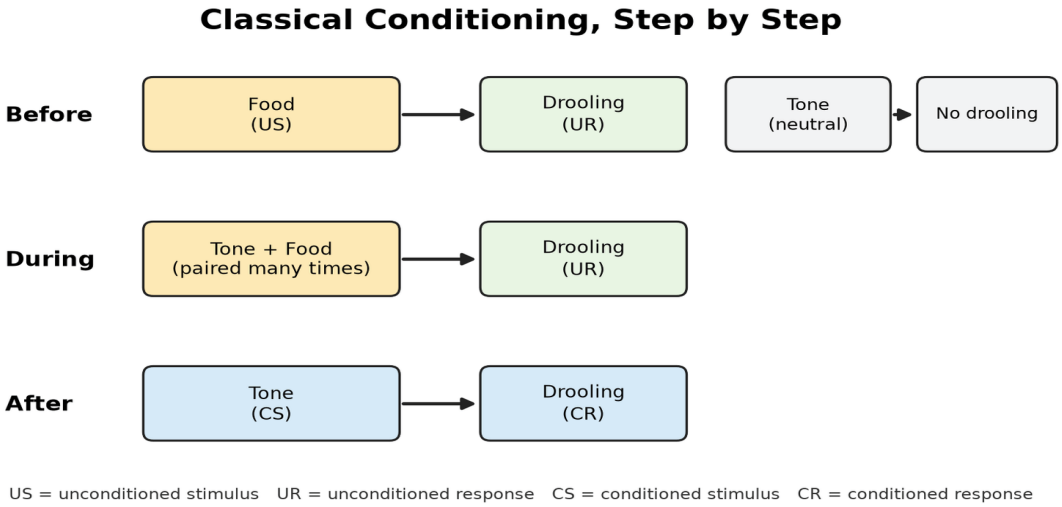
Unit 11.7: Classical Conditioning

Learning Objectives

By the end of this unit, you will be able to:

- Identify the US, UR, CS, and CR in an example.
- Give everyday examples of classical conditioning, such as taste aversion, fear, and drug cues.
- Explain prediction error, extinction, spontaneous recovery, and renewal.

In classical conditioning, an **unconditioned stimulus (US)**, like food, naturally triggers an **unconditioned response (UR)**, like drooling. A neutral stimulus, like a tone, is paired with the US until it becomes a **conditioned stimulus (CS)** that triggers a **conditioned response (CR)** on its own. The diagram below shows classical conditioning before, during, and after the tone is paired with food.



> **Image description:** Three rows. Before conditioning: food, the unconditioned stimulus (US), causes drooling, the unconditioned response (UR), while a tone is neutral and causes no drooling. During conditioning: the tone and food are paired many times, and the food causes drooling. After conditioning: the tone alone, now the conditioned stimulus (CS), causes drooling, now the conditioned response (CR). A key at the bottom spells out US, UR, CS, and CR.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Conditioning in Everyday Life

- **Taste aversion:** one bout of food poisoning can make a food disgusting for years. Rats learn to link a taste with illness, but not a light or sound with illness, showing **preparedness**: we are built to learn some links more easily than others (Garcia & Koelling, 1966). Children receiving chemotherapy developed aversions to a new ice cream eaten before treatment (Bernstein, 1978); giving an unusual candy as a "scapegoat" helped protect their usual foods (Broberg & Bernstein, 1987).
- **Fear:** a tone paired with a mild shock makes rats afraid of the tone, through the amygdala (Module 10). Similar learning helps explain some phobias.
- **Drugs:** places and objects linked to drug use can trigger responses that brace the body for the drug. Using in an unfamiliar setting, without those cues, can raise the risk of overdose (Siegel et al., 1982; Module 13).

Prediction, Extinction, and Return

Conditioning depends on surprise. If a tone already predicts food, adding a light along with it teaches little about the light; the tone "blocks" it (Kamin, 1969). Learning happens when there is a **prediction error**, a gap between what you expected and what happened.

When the CS keeps appearing without the US, the response fades: **extinction**. But extinction is new learning, not erasing. The old response can return after time passes (**spontaneous recovery**) or in a different setting (**renewal**) (Bouton, 2004). Exposure therapy for phobias uses extinction, and therapists practice in several settings to make the new learning last.

From a Peer

"After a car accident, I felt my chest tighten at every intersection. Driving the same roads again and again with someone I trusted slowly turned that down."

Check Your Understanding

1. In Pavlov's experiment, what were the US, UR, CS, and CR?
2. What is preparedness?
3. What is extinction, and does it erase the original learning?
4. What is renewal?

The answers are in the unit you just read.

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Unit 11.8: Operant Conditioning

Learning Objectives

By the end of this unit, you will be able to:

- Distinguish positive and negative reinforcement and punishment.
- Explain shaping and stimulus control.
- Describe how goal-directed actions become habits.

In operant conditioning, consequences shape behavior. A **reinforcer** is any consequence that makes a behavior more likely; a **punisher** makes it less likely. “Positive” means something is added, and “negative” means something is taken away.

Reinforcement and Punishment

Effect on behavior	Something is added	Something is removed
Behavior increases	**Positive reinforcement:** you get paid for extra shifts, so you pick up more.	**Negative reinforcement:** buckling your seatbelt stops the beeping, so you buckle up faster.
Behavior decreases	**Positive punishment:** you get a ticket for speeding, so you slow down.	**Negative punishment:** you lose phone privileges for missing curfew, so you come home on time.

Complex behaviors can be built through **shaping**, reinforcing closer and closer steps toward the goal, the way animal trainers teach tricks.

Cues and Choices

Behavior is also guided by cues that signal when a response will pay off. A **discriminative stimulus** sets the occasion for a behavior: a rat presses a lever for food only when a light is on, and you go when the left-turn arrow turns green. This is called **stimulus control**. Behavior is also a choice among options; actions are chosen more often when they earn more reinforcement than the alternatives (Herrnstein, 1970).

Goals, Habits, and the Brain

Early on, actions are goal-directed. Rats trained to make two different actions for two different treats stopped making the action whose treat had later been paired with illness (Colwill & Rescorla, 1986). After extensive training, though, behavior can become a **habit**, triggered by cues and continued even when the outcome no longer has value (Adams, 1982). Habits depend heavily on the basal ganglia.

Dopamine neurons help drive this learning. They fire more when a reward is better than expected, less when it is worse, and no differently than usual when it is just as expected, signaling the same kind of prediction error you saw in classical conditioning (Schultz et al., 1997).

Check Your Understanding

1. What is the difference between positive and negative reinforcement?
2. What is a discriminative stimulus?
3. How is a habit different from goal-directed behavior?
4. What do dopamine neurons signal during learning?

The answers are in the unit you just read.

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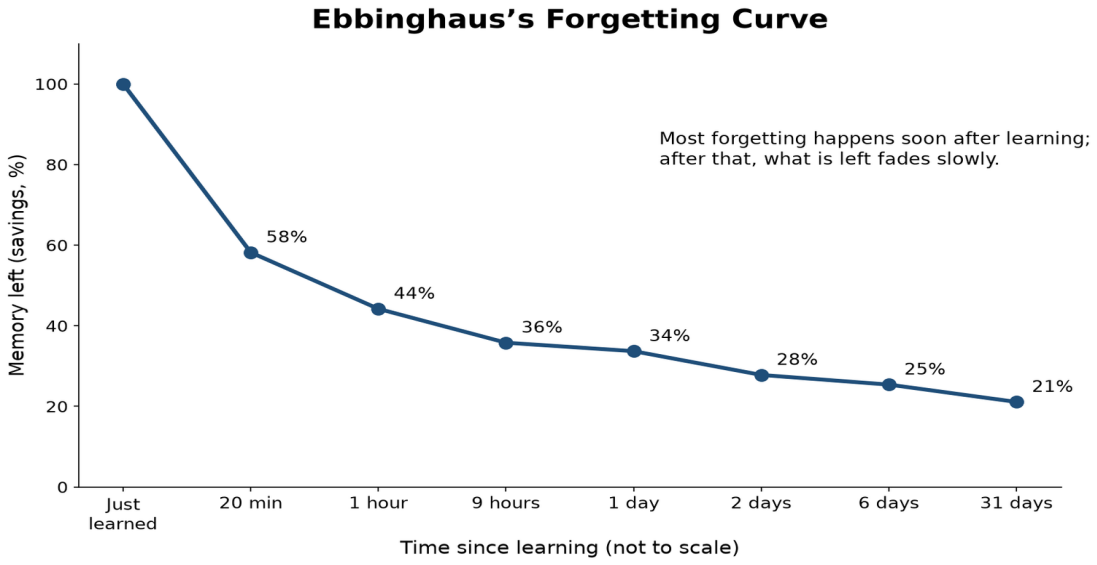
Unit 11.9: Forgetting and Amnesia

Learning Objectives

By the end of this unit, you will be able to:

- Describe the forgetting curve and the main causes of forgetting, including proactive and retroactive interference.
- Describe Alzheimer's disease, including amyloid plaques and neurofibrillary tangles.

Everyone forgets. Forgetting can be frustrating, but it is also useful: it clears out outdated details, like old passwords, so current ones are easier to find. Hermann Ebbinghaus (1885/1913) was the first to measure it. He learned lists of nonsense syllables and tested himself later, counting how much less effort relearning took. His **forgetting curve** shows that most forgetting happens soon after learning.



> **Image description:** A line graph of Ebbinghaus's 1885 results. The vertical axis shows how much of a learned list was still saved, as the percent of relearning effort saved. The line starts at 100% just after learning and falls to 58% after 20 minutes, 44% after 1 hour, 36% after 9 hours, 34% after 1 day, 28% after 2 days, 25% after 6 days, and 21% after 31 days. The time axis is not to scale. A note says most forgetting happens soon after learning, and after that what is left fades slowly.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Why We Forget

- **Encoding failure:** the information never got in. Most people can't pick the correct penny from a set of drawings, despite handling pennies for years (Nickerson & Adams, 1979).
- **Decay:** unused memories may weaken over time, though decay alone doesn't explain most forgetting.
- **Interference:** similar memories compete. In **proactive interference**, old learning disrupts new learning, like typing an old password. In **retroactive interference**, new learning disrupts old memories, like forgetting last semester's Spanish after starting French.
- **Retrieval failure:** the memory is there but out of reach, as in a tip-of-the-tongue moment, until a cue brings it back.
- **Motivated forgetting:** when people repeatedly push an unwanted memory out of mind, it becomes harder to recall later (Anderson & Green, 2001).

Alzheimer's Disease

Dementia is a decline in memory and thinking severe enough to interfere with daily life. Its most common cause is **Alzheimer's disease**, which affects an estimated 7.4 million Americans age 65 and older (Alzheimer's Association, 2026). Alois Alzheimer first described it in 1906. In the brain, a protein called beta-amyloid clumps into **amyloid plaques** between neurons, and a protein called tau forms **neurofibrillary tangles** inside them. Neurons die, the brain shrinks, and the hippocampus is hit early, which is why trouble forming new memories is often the first sign.

Close to Home

Many Valley families care for a grandparent with dementia at home. Short, simple sentences, steady daily routines, and old photos and familiar music can help, because older memories and skills often last longer than new ones. Caregivers need support too; ask a doctor or clinic about local caregiver programs.

Check Your Understanding

1. What does Ebbinghaus's forgetting curve show?
2. What is the difference between proactive and retroactive interference?
3. What two abnormal protein buildups are found in Alzheimer's disease?
4. Why is memory for new events often the first thing affected in Alzheimer's?

The answers are in the unit you just read.

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Unit 11.10: Learning Strategies That Work

Learning Objectives

By the end of this unit, you will be able to:

- Define metacognition.
- Apply the spacing effect, desirable difficulties, and transfer-appropriate processing to your own studying.

Research on memory points to a few principles that make studying pay off. In a major review of study techniques, practice testing and spreading study out over time earned the highest ratings, while rereading and highlighting earned low ones (Dunlosky et al., 2013).

Know What You Know

Metacognition is thinking about your own thinking: checking what you understand and adjusting how you study. Students often mistake familiarity for mastery. A chapter feels familiar after rereading, but that doesn't mean you can explain it. Quizzing yourself shows what you actually know.

Space It Out and Make It Effortful

Studying the same total time in several shorter sessions beats one long session, an effect called the **spacing effect** (Cepeda et al., 2006). Spacing works partly because some forgetting between sessions makes the next retrieval harder, and that effort strengthens the memory. Robert and Elizabeth Bjork call these helpful struggles **desirable difficulties** (Bjork & Bjork, 2011).

Practice the Way You'll Use It

According to **transfer-appropriate processing**, memory is best when the way you study matches the way you'll need the information (Morris et al., 1977). If an exam asks you to apply ideas, practice applying them to examples. If you'll give a speech, rehearse out loud. A nursing student practicing CPR needs hands on a mannequin, not just the manual.

No Wi-Fi Needed

The best study tools don't need a screen. Make paper flashcards and sort them into "know it" and "not yet" piles. Cover your notes and write down everything you remember, then check. Explain a concept out loud as if teaching a friend. Write a simple schedule that returns to each topic two or three times over the week. These methods work as well in a quiet corner as in a computer lab.

From a Peer

"I used to read my notes five times the night before. Now I quiz myself a little every day, and the test feels like the fourth time I've done it."

Check Your Understanding

1. What is metacognition?
2. Why does spacing out study sessions help?
3. What is transfer-appropriate processing?

> *The answers are in the unit you just read.*

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Unit 11.11: Module Wrap-Up

You made it through Module 11. Before you move on to language, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Learning is a lasting change in behavior or knowledge that comes from experience, and every memory passes through encoding, storage, and retrieval (11.1).
- Information moves through sensory memory, short-term or working memory, which can actively hold only about four meaningful chunks, and long-term memory, which has no known limit (11.2).
- Explicit memory includes events you lived (episodic memory) and general knowledge (semantic memory), while implicit memory shows up in skills and habits you use without thinking (11.2).
- Thinking about meaning, distinctiveness, and emotion all make encoding stronger, but memory can add things that weren't there, and even vivid flashbulb memories change over time (11.3).
- The case of H.M. showed that the hippocampus is needed to form new explicit memories, while skills depend on other brain systems, such as the basal ganglia and cerebellum (11.4).
- Retrieval cues work best when they match the conditions present during learning, and practicing retrieval makes memories stronger, but each retrieval is also a reconstruction that later information can change (11.5).
- In classical conditioning, a neutral cue paired with something meaningful starts to trigger a response on its own, and extinction is new learning rather than erasing, which is how exposure therapy for phobias works (11.6, 11.7).
- In operant conditioning, reinforcement makes a behavior more likely and punishment makes it less likely, and with enough training, goal-directed actions can turn into habits (11.6, 11.8).
- Most forgetting happens soon after learning, and it can come from encoding failure, interference, or retrieval failure, while Alzheimer's disease, the most common cause of dementia, hits the hippocampus early (11.9).
- Quizzing yourself and spreading study over several sessions work much better than rereading and highlighting, and a little helpful struggle while studying, called a desirable difficulty, helps you remember (11.10).

Why This Module Matters

This may be the most useful module for your life as a student. The research is clear that quizzing yourself and spacing out your study beat rereading your notes the night before, and some of the best tools, like paper flashcards and explaining ideas out loud, don't need a screen.

Learning also explains everyday reactions, like stomachs growling when the lunch truck honks, or a chest tightening at an intersection after a car accident. And many Valley families care for a grandparent with dementia at home, where steady routines, old photos, and familiar music can help, because older memories often last longer than new ones.

Module 11 ideas in everyday life

Idea	Where you met it	Where you might see it
Chunking	11.2	Remembering 559 (the Fresno area code) as one chunk instead of three digits
Encoding specificity	11.5	A song, a smell, or a place bringing back a memory
Misinformation effect	11.5	Why eyewitness memory can be wrong
Classical conditioning	11.6	Stomachs growling when the lunch truck honks, before anyone smells food
Negative reinforcement	11.8	Buckling your seatbelt to stop the beeping
Retrieval practice and spacing	11.10	Quizzing yourself a little every day instead of cramming the night before

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. How do you usually study? After this module, which study habit would you keep, and which one would you change?
2. Think of a memory you feel sure about. Could some details have changed over time? How would you know?
3. What is one habit you'd like to build or break? What cues and rewards keep it going right now?
4. Is there a smell, song, or place that brings back a strong memory for you? What does it bring back?

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Unit 11.12: References

About This Module

This module was adapted and rewritten by Michael Miguel from his earlier Learning and Memory module, which drew on the Noba modules Memory (Encoding, Storage, Retrieval) by Kathleen B. McDermott and Henry L. Roediger III, Conditioning and Learning by Mark E. Bouton, Forgetting and Amnesia by Nicole Dudukovic and Brice Kuhl, and Factors Influencing Learning by Aaron Benjamin, licensed CC BY-NC-SA 4.0. Material on memory and the brain and on Alzheimer's disease was adapted from Chapters 8 and 11 of *Biological Psychology* by Michael J. Hove and Steven A. Martinez (ROTEL Project), licensed CC BY-NC-SA 4.0. Changes: condensed and reorganized from 17 pages to 10 units, plain language for Coalinga College campus and Rising Scholars students, Central Valley examples, review questions, corrected facts, and new diagrams. Terms are defined in the book Glossary.

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MODULE 12: LANGUAGE



> **Image description:** An artistic banner titled “Language” with the line “The words we use shape our thoughts, connect us to others, and help us make sense of the world.” A young woman takes notes from an open textbook at a table with a coffee mug and laptop, while two students talk in the background. A whiteboard behind her shows “Hello,” “Hola,” “你好 (Nǐ hǎo),” “Bonjour,” and “こんにちは (Konnichiwa),” and two speech bubbles appear beside the title. This is an artistic image, not a scientific diagram.

Credit: AI-generated image created by Michael Miguel with ChatGPT (OpenAI).

Right now, your brain is turning little black marks on a page into ideas. Later today, you might switch between English and Spanish at the dinner table, text a friend in shorthand only the two of you understand, or explain something to a coworker who is new to the job. Language is so automatic that we rarely notice how much work it takes.

In this module, you’ll look at how people use language together in conversation, and then at the brain areas that make speaking and understanding possible. You’ll also see what happens when those areas are damaged, and how people can recover.

Learning Objectives

By the end of this module, you will be able to:

- Define language and give examples of how it connects people.
- Describe common ground, audience design, and turn-taking in conversation.
- Identify the locations and main jobs of Broca’s area and Wernicke’s area.
- Compare Broca’s aphasia and Wernicke’s aphasia.
- Explain why the classic two-area model of language is now seen as too simple.

Unit 12.1: Introduction to Language
Unit 12.2: How Do We Use Language?
Unit 12.3: Language in the Brain
Unit 12.4: Module Wrap-Up
Unit 12.5: References

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Unit 12.1: Introduction to Language

Learning Objectives

By the end of this unit, you will be able to:

- Define language.
- Explain why signed languages are full languages.
- Describe how putting feelings into words can calm emotion.

Think about the last real conversation you had. You chose words, put them in order, read the other person's face, and answered in a fraction of a second, all without planning most of it. That everyday skill is one of the most complex things a human brain does.

Language is a shared system of sounds, signs, or written symbols, plus rules for combining them, that people use to communicate meaning. Spoken languages and signed languages, such as American Sign Language, are both full languages with their own grammar.

Language does a lot more than pass along facts. In one study, researchers listened in on everyday conversations and found that about two-thirds of talking time was spent on social topics, such as relationships, plans, and other people (Dunbar et al., 1997). Language helps us build friendships, keep groups together, and pass on culture.

Language also connects to your body and emotions. In a brain-imaging study, simply putting a feeling into words, such as naming a face as "angry," lowered activity in the amygdala, a brain area that responds to emotional and threatening things (Lieberman et al., 2007). Naming what you feel can help calm it. This links back to the amygdala's role in fear and emotion that you met in Module 10.

In Plain Words

Language is like a team sport. You need the rules of the game (words and grammar), but you also need teammates who know the plays. The brain gives you the equipment; conversation is where the game happens.

From a Peer

"When I write down what's bothering me, even just a few words, it stops spinning around in my head. I didn't know there was actual brain research behind that."

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Unit 12.2: How Do We Use Language?

Learning Objectives

By the end of this unit, you will be able to:

- Describe conversation as joint action.
- Explain common ground, audience design, and interactive alignment.
- Describe how people take turns in conversation.

Imagine you text a friend, “Meet me at our usual spot.” You don’t need to say where, because you both know. Conversation works because people cooperate. The psychologist Herbert Clark (1996) described language use as a **joint action**, something speakers and listeners do together, like two people carrying a couch.

Common Ground

Common ground is the knowledge, experiences, and assumptions two people share. It lets us use shortcuts, like “our usual spot” or an inside joke. When common ground is missing, messages break down. If you tell your lab partner, “I’ll do the methods, you do the rest,” you may each picture a different “rest.” A quick check, such as “So you’re doing the results and the references?”, builds common ground and prevents the mix-up.

Audience Design

We constantly adjust how we talk to fit our listener, a habit called **audience design**. For example, you’d explain a movie differently to a friend who has seen it than to one who hasn’t. In one study, speakers gave more detail when they thought the listener was less likely to know what they were describing (Fussell & Krauss, 1992). You probably talk differently to a professor, a little cousin, and your best friend, without thinking about it.

Taking Turns

Conversation is also remarkably fast. In a study of ten languages from around the world, the most common gap between one speaker finishing and the next starting was less than 200 milliseconds, under a fifth of a second (Stivers et al., 2009). To answer that quickly, listeners must plan their reply while the other person is still talking. Partners in a smooth conversation also start to echo each other’s words, phrases, and even accents, a process called **interactive alignment** (Pickering & Garrod, 2004).

Close to Home

Many students in the Valley move between Spanish and English all day, and sometimes inside a single sentence: “Ya terminé the homework, so let’s go.” Switching languages like this, called code-switching, follows its own grammar rules and is a skill, not a mistake (Poplack, 1980). Bilingual speakers often switch to match their audience, which is audience design at work.

Check Your Understanding

1. What is common ground?
2. What is audience design?
3. About how long is the most common gap between speakers in conversation?

The answers are in the unit you just read.

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Unit 12.3: Language in the Brain

Learning Objectives

By the end of this unit, you will be able to:

- Describe the roles of Broca's area, Wernicke's area, and the arcuate fasciculus.
- Compare Broca's aphasia and Wernicke's aphasia.
- Explain why language depends on a wide brain network.

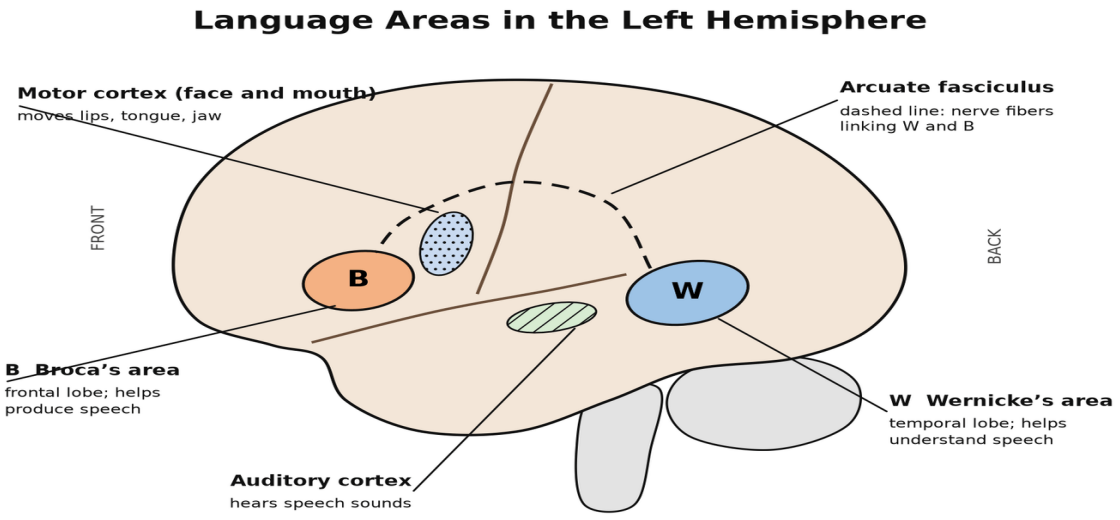
Picture someone who knows exactly what they want to say but can only get out a word or two. Now picture someone who speaks smoothly, with plenty of words, but whose sentences make little sense. Both situations happen after certain kinds of brain damage, and they taught scientists a lot about where language lives in the brain.

Broca's Area

In 1861, the French physician Paul Broca studied a man who could understand speech but could say almost nothing except the syllable "tan." After the man died, Broca found damage in the lower part of the left frontal lobe (Broca, 1861). This region, now called **Broca's area**, helps plan and produce speech. It sits just in front of the part of the motor cortex that moves the lips, tongue, and jaw. Modern scans of the man's preserved brain show the damage reached deeper areas too (Dronkers et al., 2007).

Wernicke's Area

In 1874, the German physician Carl Wernicke described patients who spoke fluently but had trouble understanding others. Their damage was farther back, in the upper part of the left temporal lobe, near the auditory cortex (Wernicke, 1874). This region, now called **Wernicke's area**, helps people understand spoken words. A bundle of nerve fibers, the **arcuate fasciculus**, links Wernicke's area with Broca's area.



Simplified side view of the left hemisphere. Language also uses many other areas in both hemispheres.

> **Image description:** A simplified side view of the brain's left hemisphere, with the front of the brain on the left, titled "Language Areas in the Left Hemisphere." Broca's area (marked B) sits in the lower frontal lobe and helps produce speech. Wernicke's area (marked W) sits farther back, in the upper temporal lobe, and helps understand speech. The auditory cortex, which hears speech sounds, lies between them in the temporal lobe, and the face and mouth part of the motor cortex, which moves the lips, tongue, and jaw, lies just above and behind Broca's area. A

dashed line, the arcuate fasciculus, arcs from Wernicke's area to Broca's area. A note says language also uses many other areas in both hemispheres.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Aphasia

Aphasia is a loss or weakening of language ability caused by brain damage, most often from a stroke (National Institute on Deafness and Other Communication Disorders, n.d.). Aphasia affects language, not intelligence.

- People with **Broca's aphasia** speak slowly and with great effort, often leaving out small words: "Walk… dog… park." They usually understand everyday speech fairly well and know their speech is coming out wrong.
- People with **Wernicke's aphasia** speak easily and in normal rhythm, but their words may be the wrong ones or even made up, so the meaning gets lost. They have trouble understanding others and may not notice their own errors.

Beyond Two Areas

In most people, these language areas are in the left hemisphere. In one study, that was true for about 96% of strongly right-handed people and about 73% of strongly left-handed people (Knecht et al., 2000). Deaf people who use sign language and have left-hemisphere damage can develop aphasia in signing, which shows these areas handle language itself, not just sound (Hickok et al., 1996).

Still, the classic two-area model is too simple. Brain imaging shows that language depends on a large network spread across both hemispheres (Tremblay & Dick, 2016). That is one reason many people with aphasia improve over time, especially with speech-language therapy, as other parts of the network take on more of the work.

From a Peer

"After my grandma's stroke, she couldn't find her words, and she got so frustrated. Speech therapy every week helped a lot. Now she can tell her stories again, just slower."

Check Your Understanding

1. Which lobe is Broca's area in?
2. What kind of aphasia makes speech fluent but hard to understand?
3. What is the most common cause of aphasia?
4. What does the arcuate fasciculus connect?

The answers are in the unit you just read.

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Unit 12.4: Module Wrap-Up

You made it through Module 12. Before you move on to psychopharmacology, the study of how drugs affect the brain, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Language is a shared system of sounds, signs, or written symbols, plus rules for combining them, and signed languages such as American Sign Language are full languages with their own grammar (12.1).
- Much of everyday talk is about relationships and other people, and simply putting a feeling into words can lower activity in the amygdala (12.1).
- Conversation is teamwork that depends on common ground, the knowledge two people share, and audience design, the way you adjust how you talk to fit your listener (12.2).
- People take turns in conversation remarkably fast, so listeners have to plan their reply while the other person is still talking (12.2).
- Switching between languages, called code-switching, follows its own grammar rules and is a skill, not a mistake (12.2).
- Broca's area in the left frontal lobe helps plan and produce speech, and Wernicke's area in the left temporal lobe helps people understand spoken words (12.3).
- People with Broca's aphasia speak slowly and with great effort, while people with Wernicke's aphasia speak easily but have trouble making sense and understanding others (12.3).
- Language depends on a large network across both hemispheres, not just two areas, which is one reason many people with aphasia improve with speech-language therapy (12.3).

Why This Module Matters

Language is how you build friendships, keep families together, and pass on culture. Many students in the Valley move between Spanish and English all day, sometimes inside a single sentence, and that's a skill, not a mistake. You use audience design every time you talk differently to a professor, a little cousin, and your best friend. And if someone you love has a stroke that affects their speech, knowing about aphasia can help you be patient: it affects language, not intelligence, and speech therapy helps many people improve.

Module 12 ideas in everyday life

Idea	Where you met it	Where you might see it
Common ground	12.2	Texting "meet me at our usual spot" and knowing your friend will understand
Audience design	12.2	Explaining a movie differently to a friend who hasn't seen it
Code-switching	12.2	"Ya terminé the homework, so let's go."
Putting feelings into words	12.1	Writing down what's bothering you so it stops spinning around in your head
Aphasia	12.3	A grandparent getting their words back, slowly, with weekly speech therapy after a stroke

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and look back at them when you finish the book.

1. How many ways of talking do you use in a normal day, with family, friends, at work, or in class? What changes from one to the next?
2. Do you switch between languages or ways of speaking? How does it feel when someone treats that as a mistake instead of a

skill?
3. Think of a time a conversation went wrong because you and the other person didn't share the same common ground. What would have helped?
4. When something is bothering you, does putting it into words help? What's your favorite way to do that: talking, writing, praying, or something else?

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Unit 12.5: References

About This Module

This module was adapted and rewritten by Michael Miguel from his earlier Language module, which drew on the Noba module Language and Language Use by Yoshihisa Kashima, licensed CC BY-NC-SA 4.0. Changes: rewritten in plain language for Coalinga College campus and Rising Scholars students; the units on gossip, group identity, and the psychological effects of language were cut, and a new unit on language in the brain was added; a Central Valley example was added; facts were checked and corrected. The web addresses below are for reference only; you don't need them to use this book.

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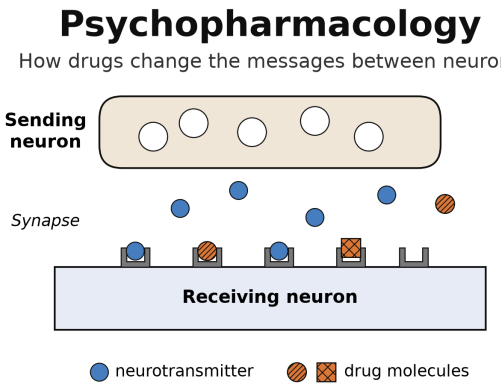
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MODULE 13: PSYCHOPHARMACOLOGY



> **Image description:** A banner titled “Psychopharmacology: How drugs change the messages between neurons.” A sending neuron at the top holds round sacs of chemical messengers, and blue circles (neurotransmitters) cross the gap, labeled “Synapse,” to cup-shaped receptors on a receiving neuron below. Some receptors hold a neurotransmitter, one holds a striped orange circle (a drug that acts like the neurotransmitter), one holds a crossed orange square (a drug that blocks the receptor), and one is empty. A key at the bottom labels the neurotransmitter and the drug molecules.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Your morning coffee, a pain reliever after a hard workout, a prescription for anxiety, a cold beer at a barbecue: all of these change how your brain works. Some drugs help people heal, some cause serious harm, and many do both, depending on the dose, the person, and the situation.

In this module, you’ll follow a drug from the moment it enters the body to the moment it reaches a synapse. You’ll see why two people can react very differently to the same medicine, how drugs speed up or block messages between neurons, and what science says about addiction, recovery, and safer use.

Learning Objectives

By the end of this module, you will be able to:

- Define psychopharmacology and psychoactive drugs.
- Describe the four steps of pharmacokinetics (ADME) and explain why the route of a drug matters.
- Explain how genes, food, and age can change the way a person’s body handles a drug.
- Describe tolerance, withdrawal, and addiction, and identify treatments that support recovery.
- Compare agonists, antagonists, and reuptake inhibitors, with an example of each.
- Identify the main classes of psychoactive drugs and their main effects and risks.

Unit 13.1: Introduction to Psychopharmacology
Unit 13.2: Pharmacokinetics: What and Why?
Unit 13.3: Psychotropic Drugs and Metabolism
Unit 13.4: Addiction and Other Controversial Issues
Unit 13.5: How Drugs Affect Neurotransmitters
Unit 13.6: Module Wrap-Up

Unit 13.7: References

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Unit 13.1: Introduction to Psychopharmacology

Learning Objectives

By the end of this unit, you will be able to:

- Define psychopharmacology and psychoactive drug.
- Distinguish pharmacokinetics from pharmacodynamics.

Every day, millions of people take something that changes their brain chemistry. Some take medicine to ease depression, focus attention, or sleep. Others reach for caffeine, nicotine, or alcohol. Whether the effect is helpful or harmful, these substances all work the same basic way: they change how neurons talk to each other.

Psychopharmacology is the scientific study of how drugs affect the brain, behavior, mood, and thinking. A **psychoactive drug** is any substance that changes perception, mood, thinking, or behavior by acting on the nervous system. The field draws on psychology, neuroscience, chemistry, and medicine.

Researchers in this field ask two big questions. The first is **pharmacokinetics**: how a drug moves through the body, which you'll study in Units 13.2 and 13.3. The second is **pharmacodynamics**: what a drug does once it reaches its target, such as a receptor on a neuron, covered in Unit 13.5.

No drug acts on just one brain area or one neurotransmitter. That is why medicines have side effects. A medicine that raises serotonin to ease depression can also upset the stomach or change sleep, because serotonin works in the gut and in sleep circuits too. Finding the right medicine and dose often takes careful adjustment.

From a Peer

"When I started medication for anxiety, I thought it would just make me calmer. It also changed my sleep and my focus. Learning how these drugs work helped me understand why my doctor kept adjusting the dose."

Check Your Understanding

1. What is psychopharmacology?
2. What is the difference between pharmacokinetics and pharmacodynamics?
3. Why do medicines have side effects?

The answers are in the unit you just read.

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Unit 13.2: Pharmacokinetics: What and Why?

Learning Objectives

By the end of this unit, you will be able to:

- Describe the four steps of ADME.
- Explain the role of the blood–brain barrier.
- Explain how the route of administration and the first-pass effect change a drug's effects.

Why does a nasal spray work in minutes while a pill can take an hour? The answer is pharmacokinetics, the study of how a drug moves through the body. It decides how fast a drug starts working, how strong it feels, and how long it lasts.

The Four Steps: ADME

Pharmacokinetics is often summed up as **ADME**, for absorption, distribution, metabolism, and excretion.

The four steps of pharmacokinetics (ADME)

Step	What happens	Why it matters for the mind
Absorption	The drug gets into the bloodstream from where it entered the body.	Faster absorption usually means a quicker, stronger effect.
Distribution	The blood carries the drug around the body, including to the brain.	Only drugs that can cross the **blood–brain barrier** act directly on the brain.
Metabolism	The body, mostly the liver, breaks the drug down.	How fast this happens changes how long a drug stays active.
Excretion	The body removes the drug and its leftovers, mostly in urine.	Slow removal means longer effects and a higher risk of buildup.

In Plain Words

Think of a drug as a delivery truck. Absorption is getting on the freeway, distribution is driving to every neighborhood, metabolism is the recycling center breaking down old packages, and excretion is hauling the trash away. The brain is a gated neighborhood: only some trucks get past the gate.

Why the Route Matters

The way a drug enters the body is its **route of administration**. Common routes are swallowing, inhaling, injecting, and absorbing through the skin with a patch. A swallowed pill passes through the stomach and then the liver before reaching the rest of the body. The liver breaks down part of the dose on this first trip, which is called the **first-pass effect**, so less of the drug reaches the brain.

Inhaled and injected drugs skip that first trip and can reach the brain within seconds. A faster, stronger rush also raises the risk of addiction, which is one reason smoked or injected drugs are especially risky. For medicines, doctors pick the route that gives a steady, safe level in the blood.

Check Your Understanding

1. What do the letters ADME stand for?
2. What is the first-pass effect?
3. Why do inhaled or injected drugs act faster than pills?

The answers are in the unit you just read.

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Unit 13.3: Psychotropic Drugs and Metabolism

Learning Objectives

By the end of this unit, you will be able to:

- Explain how cytochrome P450 liver enzymes break down drugs.
- Explain why grapefruit can change drug levels.
- Define pharmacogenomics.

Two people take the same antidepressant at the same dose. One feels better in a few weeks; the other feels dizzy and sick. Often, the difference is not willpower or attitude. It is how fast each person's body breaks the drug down.

The Liver's Drug-Processing Enzymes

Much of drug metabolism is done by a family of liver enzymes called **cytochrome P450** enzymes. If these enzymes work slowly, a drug builds up in the blood and side effects increase. If they work fast, the drug may be cleared before it can help.

Grapefruit: A Food That Changes Drug Levels

Grapefruit juice blocks one of these enzymes, CYP3A4, in the gut. As a result, more of certain medicines gets into the blood. More than 85 drugs are known to interact with grapefruit, including some heart, pain, and psychiatric medicines, and a single glass can matter (Bailey et al., 2013). That is why some prescription labels say to avoid grapefruit.

Genes and Drug Response

Genes also change how these enzymes work. Based on a genetic test, people can be grouped by how fast they process certain drugs (Caudle et al., 2017):

Metabolizer types for a drug-processing enzyme

Type	How fast drugs are broken down	Possible result
Poor metabolizer	Very slowly	The drug builds up; side effects or toxic levels are more likely.
Intermediate metabolizer	Somewhat slowly	Drug levels stay higher than expected.
Normal metabolizer	At the expected rate	The usual dose usually works as expected.
Ultrarapid metabolizer	Very quickly	The drug may be cleared before it can work.

The study of how genes shape drug response is called **pharmacogenomics**. Genetic testing can help doctors choose some medicines and doses, but it is not available or useful for every drug, and insurance does not always cover it. Age, liver health, other medicines, and diet matter too.

From a Peer

"My cousin went through three antidepressants before one worked. Learning about metabolism made me realize she wasn't 'doing it wrong.' Her body just handles those drugs differently."

Check Your Understanding

1. Which family of liver enzymes breaks down many drugs?
2. What does grapefruit juice do to some medicines?
3. What can happen to a poor metabolizer who takes a usual dose?

The answers are in the unit you just read.

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Unit 13.4: Addiction and Other Controversial Issues

Learning Objectives

By the end of this unit, you will be able to:

- Define tolerance and withdrawal.
- Describe substance use disorder as a treatable brain-based condition.
- Explain special risks for children and older adults, including polypharmacy.

Some drugs that help people can also be misused, and some groups of people get medicines that were never well tested in people like them. This unit looks at both problems.

Tolerance, Withdrawal, and Addiction

With repeated use of many drugs, the brain adapts. **Tolerance** means a person needs more of a drug to get the same effect. **Withdrawal** is the set of uncomfortable or dangerous symptoms, often the opposite of the drug's effects, that appear when a person stops using it. Tolerance and withdrawal can happen even with medicines taken exactly as prescribed.

Addiction is different. Doctors call it a **substance use disorder**: continuing to use a substance despite harm, with craving and loss of control. Repeated drug use changes the brain's reward, stress, and self-control circuits, which helps explain why quitting is so hard (Volkow et al., 2016). Addiction is a treatable health condition, not a moral failing.

For opioid use disorder, the medicines methadone, buprenorphine, and naltrexone all reduce opioid cravings and make a return to opioid use less likely, and people treated long term with methadone or buprenorphine are up to 50% less likely to die (National Academies of Sciences, Engineering, and Medicine, 2019).

In Plain Words

Tolerance is like getting used to a loud room: after a while, you need the music even louder to notice it. Withdrawal is what happens when the music suddenly stops and the room feels painfully quiet.

From a Peer

"Recovery wasn't one big decision. It was a lot of small ones, every day, with people around me who didn't give up on me. Medication helped my body. My people helped the rest."

Children and Older Adults

Most psychiatric medicines were first tested in adults, so less is known about their long-term effects on developing brains. Diagnoses have also shifted quickly. In one study, U.S. office visits for youth that included a bipolar disorder diagnosis rose about 40-fold between the mid-1990s and the early 2000s, raising questions about diagnosis and prescribing (Moreno et al., 2007).

Older adults face different risks. As people age, the liver and kidneys clear drugs more slowly, so a usual dose can hit harder. Many older adults take several medicines at once, called **polypharmacy**, which raises the chance of interactions. Experts list medicines that older adults should usually avoid, such as many sleep and anxiety drugs that raise the risk of confusion and falls (American Geriatrics Society Beers Criteria Update Expert Panel, 2023).

Check Your Understanding

1. What is tolerance?
2. Name one medicine used to treat opioid use disorder.
3. What is polypharmacy?

The answers are in the unit you just read.

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Unit 13.5: How Drugs Affect Neurotransmitters

Learning Objectives

By the end of this unit, you will be able to:

- Distinguish agonists, antagonists, and reuptake inhibitors.
- Compare the major classes of psychoactive drugs.

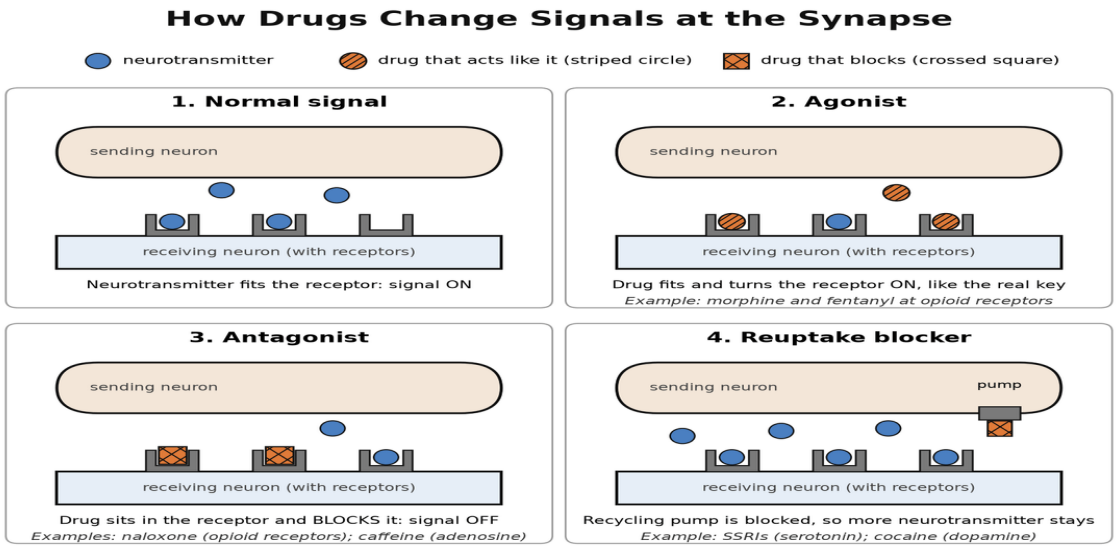
In 1943, the Swiss chemist Albert Hofmann accidentally absorbed a tiny amount of a compound he had made from a fungus that grows on grain. He soon felt restless and dizzy and saw streams of colors and shapes. The compound was LSD (lysergic acid diethylamide), and it showed that a dose measured in millionths of a gram can transform a person's experience (Hofmann, 1980).

Agonists, Antagonists, and Reuptake

As you learned in Module 3, neurons communicate by releasing neurotransmitters that fit into receptors, like keys into locks. Most psychoactive drugs work at this step.

- An **agonist** fits a receptor and activates it, mimicking or boosting the natural messenger. Morphine and fentanyl are agonists at opioid receptors, the same receptors the body's own endorphins use.
- An **antagonist** fits a receptor but blocks it, so the natural messenger can't act. Caffeine blocks receptors for adenosine, a chemical that builds up during the day and makes you sleepy.
- A **reuptake inhibitor** blocks the pump that recycles a neurotransmitter back into the sending neuron, so more of it stays in the synapse. Selective serotonin reuptake inhibitors (SSRIs), a common type of antidepressant, do this for serotonin; cocaine does it for dopamine.

The diagram below compares a normal signal with the effects of an agonist, an antagonist, and a reuptake blocker.



> **Image description:** A four-panel diagram titled "How Drugs Change Signals at the Synapse." Each panel shows a sending neuron above a receiving neuron with cup-shaped receptors. Panel 1, Normal signal: neurotransmitters (blue circles) fit the receptors, and the signal is on. Panel 2, Agonist: drug molecules (striped circles) fit the receptors and turn them on like the real key; example, morphine and fentanyl at opioid receptors. Panel 3, Antagonist: drug molecules (crossed squares) sit in the receptors and block them, so the signal is off; examples, naloxone at opioid receptors and caffeine at adenosine receptors. Panel 4, Reuptake blocker: a crossed square blocks the recycling

pump on the sending neuron, so more neurotransmitter stays in the synapse; examples, SSRIs (serotonin) and cocaine (dopamine).

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Classes of Psychoactive Drugs

Major classes of psychoactive drugs

Class	Examples	Main effects	Medical uses	Main risks
Depressants	Alcohol, benzodiazepines (such as Xanax), barbiturates	Slow brain activity, mostly by boosting the calming neurotransmitter GABA (gamma-aminobutyric acid)	Anxiety, sleep problems, seizures (benzodiazepines)	Dependence; dangerous withdrawal; slowed breathing, especially when mixed with opioids
Stimulants	Caffeine, nicotine, cocaine, amphetamines, methamphetamine	Raise alertness and energy; many increase dopamine and norepinephrine	Attention-deficit/ hyperactivity disorder (ADHD), narcolepsy	Addiction, heart strain, anxiety, poor sleep
Opioids	Morphine, oxycodone, heroin, fentanyl	Relieve pain and can cause euphoria by acting on opioid receptors	Severe pain	Addiction; overdose by slowed or stopped breathing
Hallucinogens	LSD, psilocybin (“mushrooms”), mescaline	Change perception, mood, and sense of time, mainly through serotonin receptors	None approved; some are being studied for depression and post-traumatic stress disorder (PTSD)	Panic, risky behavior, rare lasting visual changes
Cannabinoids	THC (tetrahydrocannabinol) and CBD (cannabidiol) from cannabis	Change mood, perception, and appetite through cannabinoid receptors	A CBD medicine for two rare seizure disorders; THC-like medicines for chemotherapy nausea	Memory and attention problems, cannabis use disorder

Some drugs don’t fit neatly in one class. MDMA (“ecstasy” or “molly”) is chemically similar to amphetamine and acts mostly as a stimulant, releasing serotonin, dopamine, and norepinephrine, but it can also mildly change perception (National Institute on Drug Abuse, n.d.). LSD and psilocybin mainly act on one type of serotonin receptor (Nichols, 2016). Cannabinoid medicines are described by the National Center for Complementary and Integrative Health (n.d.).

Close to Home

Fentanyl is up to 50 times stronger than heroin (Centers for Disease Control and Prevention, n.d.), and it is now often hidden in fake pills and other drugs, in the Valley as across California. Naloxone (Narcan) is an opioid antagonist: it knocks opioids off their receptors and can reverse an overdose in minutes. Since 2023, naloxone nasal spray has been sold without a prescription (U.S. Food and Drug Administration, 2023), so anyone can carry it and save a life.

Check Your Understanding

1. What is the difference between an agonist and an antagonist?
2. What do SSRIs block?
3. Which class of drugs slows breathing and can cause fatal overdose?
4. How does naloxone reverse an opioid overdose?

The answers are in the unit you just read.

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Unit 13.6: Module Wrap-Up

You made it through Module 13. Before you move on to the final module, on psychological disorders, take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- Psychopharmacology is the study of how drugs affect the brain, behavior, mood, and thinking, and a psychoactive drug is any substance that changes perception, mood, thinking, or behavior by acting on the nervous system (13.1).
- No drug acts on just one brain area or one neurotransmitter, which is why medicines have side effects (13.1).
- Pharmacokinetics describes how a drug moves through the body in four steps, absorption, distribution, metabolism, and excretion (ADME), and only drugs that can cross the blood–brain barrier act directly on the brain (13.2).
- Inhaled and injected drugs skip the first-pass effect and can reach the brain within seconds, and that faster, stronger rush raises the risk of addiction (13.2).
- Liver enzymes, genes, food such as grapefruit juice, and age all change how a person's body handles a drug, which is why two people can react very differently to the same dose (13.3, 13.4).
- Tolerance means needing more of a drug for the same effect, withdrawal is the set of symptoms that appear when you stop, and addiction, called a substance use disorder, is a treatable health condition, not a moral failing (13.4).
- For opioid use disorder, the medicines methadone, buprenorphine, and naltrexone reduce cravings and make a return to opioid use less likely (13.4).
- An agonist activates a receptor, an antagonist blocks it, and a reuptake inhibitor, such as an SSRI, keeps more of a neurotransmitter in the synapse (13.5).
- The major classes of psychoactive drugs, depressants, stimulants, opioids, hallucinogens, and cannabinoids, each have their own effects and risks, and naloxone (Narcan) can reverse an opioid overdose in minutes (13.5).

Why This Module Matters

Every day, millions of people use something that changes their brain chemistry, from morning coffee to prescribed medicine. Knowing how drugs work can help you ask better questions about your own medicines, like why a dose needs adjusting or why a label says to avoid grapefruit. It can help you understand a cousin who went through several antidepressants before one worked, or a friend in recovery.

And it can save a life: fentanyl is now often hidden in fake pills and other drugs, in the Valley as across California, and naloxone nasal spray is sold without a prescription, so anyone can carry it.

Module 13 ideas in everyday life

Idea	Where you met it	Where you might see it
Antagonist	13.5	Caffeine blocking adenosine, the chemical that builds up during the day and makes you sleepy
Drug interactions	13.3	A prescription label that says to avoid grapefruit
Metabolizer types	13.3	Someone trying more than one antidepressant before finding one that works
Polypharmacy	13.4	An older relative taking several medicines at once
Naloxone	13.5	Carrying Narcan nasal spray to reverse an opioid overdose

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot

your thoughts in a notebook and look back at them when you finish the book.

1. Which psychoactive substances are part of your regular day, like caffeine? How do you think about them differently after this module?
2. Think about a medicine you or someone close to you takes. What questions would you now want to ask a doctor or pharmacist about it?
3. This module describes addiction as a treatable health condition, not a moral failing. How does that compare with what you grew up hearing?
4. One student described recovery as “a lot of small decisions, every day.” What small daily choices help you take care of your health?

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Unit 13.7: References

About This Module

This module was adapted and rewritten by Michael Miguel from his earlier Psychopharmacology module and the Psychoactive Drugs unit of his earlier Consciousness and Attention module, which drew on Chapter 5, Psychopharmacology, of Biological Psychology by Michael J. Hove and Steven A. Martinez (ROTEL Project, 2024), licensed CC BY-NC-SA 4.0. Changes: rewritten in plain language for Coalinga College campus and Rising Scholars students; two introduction pages merged; fictional case studies replaced with real research; a new unit on how drugs affect neurotransmitters added; a Central Valley example added; facts checked and corrected. The web addresses below are for reference only; you don't need them to use this book.

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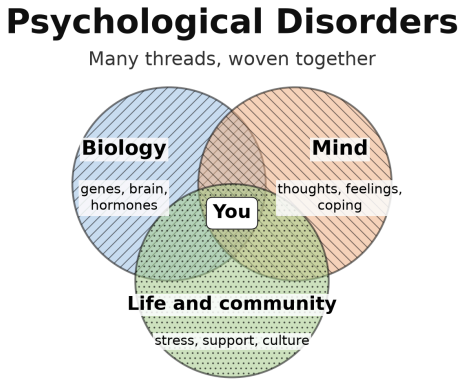
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MODULE 14: PSYCHOLOGICAL DISORDERS



> **Image description:** An artistic illustration, not a scientific diagram. A person's head is shown in side profile, drawn in glowing blue light against a dark background, with a glowing brain inside. Threads of blue, violet, and orange light swirl around the head, tangled in some places and smoothing out in others, suggesting the many influences on mental health and the path toward recovery.

Credit: AI-generated image created for Biological Psychology (Coalinga College Ed.).



> **Image description:** A banner titled “Psychological Disorders: Many threads, woven together.” Three overlapping circles are labeled Biology (genes, brain, hormones), Mind (thoughts, feelings, coping), and Life and community (stress, support, culture). Where all three overlap, a box reads “You.”

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Almost everyone knows someone who has lived with depression, anxiety, trauma, or another mental health condition. Maybe it’s a friend, a parent, a coworker, or you. These conditions are common, they are real health conditions, and many of them respond well to treatment.

In this module, you’ll look at what makes something a psychological disorder and how biology, life experience, and community work together. Then you’ll explore five conditions, schizophrenia, depression, bipolar disorder, anxiety and OCD, and PTSD, with a focus on the brain and on what helps people recover.

Some of this material can bring up hard feelings. That's normal. If you or someone you know is struggling, talk with a counselor, health care provider, or mental health staff member you trust. In the United States, you can also call or text 988, the Suicide & Crisis Lifeline, any time.

Learning Objectives

By the end of this module, you will be able to:

- Describe how psychological disorders are defined and diagnosed.
- Explain the biopsychosocial approach and the diathesis–stress model.
- Describe the main symptoms of schizophrenia and the role of dopamine.
- Compare major depressive disorder and bipolar disorder, and describe their main treatments.
- Explain how the amygdala and prefrontal cortex are involved in anxiety, OCD, and PTSD.
- Use person-first, respectful language to talk about mental health.

Close message
Learn more
Welcome to your new guide!
Click on "New" to build out your guide.

Unit 14.1: Understanding Psychological Disorders
Unit 14.2: Schizophrenia
Unit 14.3: Depression and Bipolar Disorder
Unit 14.4: Anxiety and OCD
Unit 14.5: PTSD and Trauma
Unit 14.6: Module Wrap-Up
Unit 14.7: References

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Unit 14.1: Understanding Psychological Disorders

Learning Objectives

By the end of this unit, you will be able to:

- Define a psychological disorder and describe how the DSM-5-TR is used.
- Explain the biopsychosocial approach and the diathesis–stress model, including the role of culture.
- Explain why person-first language matters.

Everyone feels sad after a loss or nervous before a big test. When does a normal feeling become a disorder? There is no single line, but professionals look at a few key questions.

What Is a Psychological Disorder?

A **psychological disorder** is a pattern of thoughts, feelings, or behaviors that causes significant distress or makes it hard to function in daily life, such as at school, work, or home. It reflects a problem in how the mind or brain is working, and it is more than an expected response to a hard event. Grief after a death, for example, is expected and is not a disorder by itself (American Psychiatric Association [APA], 2022).

In the United States, professionals diagnose these conditions using the **DSM-5-TR**, the *Diagnostic and Statistical Manual of Mental Disorders* (APA, 2022). Much of the world uses a similar system, the International Classification of Diseases (ICD-11). Both describe disorders by their symptoms, because there is not yet a blood test or brain scan that can diagnose most of them.

Many Causes Working Together

Most researchers take a **biopsychosocial** approach: disorders come from biological factors (genes, brain chemistry), psychological factors (thinking patterns, coping), and social factors (stress, support, culture) working together. The **diathesis–stress model** adds that a person's vulnerability, or diathesis, combines with life stress. Someone with high vulnerability may develop symptoms after moderate stress, while someone with low vulnerability may only do so after severe stress (Walker & Diforio, 1997).

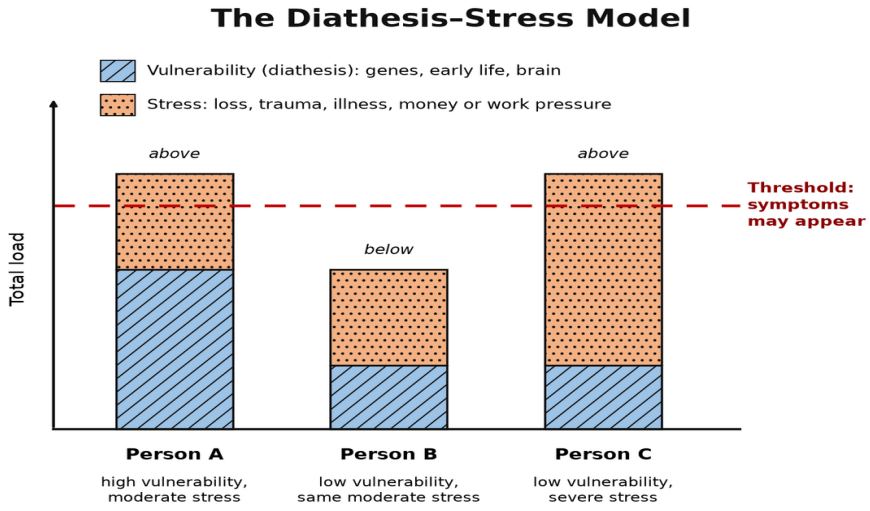


Illustration only, not real data. Support, coping skills, and treatment can lower the load or raise the threshold.

Image description: An illustration titled "The Diathesis–Stress Model." Three stacked bars show total load, made

> of vulnerability (striped: genes, early life, brain) and stress (dotted: loss, trauma, illness, money or work pressure). A dashed line marks the threshold where symptoms may appear. Person A has high vulnerability and moderate stress and goes above the line. Person B has low vulnerability and the same moderate stress and stays below it. Person C has low vulnerability but severe stress and goes above it. A note says this is an illustration, not real data, and that support, coping skills, and treatment can lower the load or raise the threshold.

Credit: Diagram by Michael Miguel for Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0.

Epigenetics, which you met in Module 4, helps explain how stress "gets under the skin." In mice, about 10 days of repeated social stress switched down a gene that supports healthy neurons in the hippocampus, and an antidepressant helped switch it back on (Tsankova et al., 2006). In a study of donated human brain tissue, people with a history of childhood abuse had extra chemical tags that turned down a gene for stress-hormone receptors in the hippocampus (McGowan et al., 2009). These changes are not destiny: support and treatment can change how genes are used.

Culture also shapes how people experience and describe distress. The DSM-5-TR includes **cultural concepts of distress**: the ways people in a culture experience, understand, and communicate suffering.

One example is *ataque de nervios*, described especially among Puerto Ricans and other Latino communities. It is an episode of intense emotional upset, often after stressful family news, with a sense of being out of control. Afterward, people usually return quickly to their usual selves. It can be a culturally normal response to overwhelming stress, not automatically a disorder (Roche-Miranda et al., 2023). So when someone describes distress in their own cultural terms, it's worth listening closely.

Words Matter

Stigma keeps many people from seeking help. Using **person-first language**, such as "a person with schizophrenia" instead of "a schizophrenic," reminds us that a diagnosis is something a person has, not who they are.

From a Peer

"When I learned that trauma can change how genes work in the brain, it was the first time science made me feel understood instead of judged. I'm not broken. I'm carrying something I didn't choose, and I can still work with it."

Check Your Understanding

1. What manual do U.S. professionals use to diagnose psychological disorders?
2. What are the three parts of the biopsychosocial approach?
3. What does "diathesis" mean?

The answers are in the unit you just read.

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Unit 14.2: Schizophrenia

Learning Objectives

By the end of this unit, you will be able to:

- Compare positive, negative, and disorganized symptoms of schizophrenia.
- Describe the dopamine hypothesis.
- Describe how antipsychotic medicine and other supports help recovery.

Imagine hearing a voice commenting on everything you do, when no one is there. For some people with schizophrenia, this is a daily experience. Schizophrenia is often misunderstood. It does not mean a "split personality," and with treatment and support, many people with schizophrenia live full lives.

Symptoms

Schizophrenia is a disorder that involves major changes in thinking, perception, emotion, and behavior. It affects roughly 0.3% to 0.7% of people at some point in life, and it usually begins between the late teens and the mid-30s (APA, 2022). Its symptoms fall into three groups:

- **Positive symptoms** are experiences that are added: **hallucinations**, which are perceptions without a real source, most often hearing voices, and **delusions**, which are strong false beliefs, such as believing others are plotting against you.
- **Negative symptoms** are things that are reduced: less emotional expression, less speech, less motivation, and pulling away from others.
- **Disorganized symptoms** include speech that jumps from topic to topic and unusual movements or behavior.

In Plain Words

"Positive" and "negative" here don't mean good and bad. Think of math: positive symptoms add something, like a voice no one else hears. Negative symptoms subtract something, like the energy to see friends.

The Brain and Schizophrenia

Genes play a large role: twin studies estimate heritability at about 80% (Sullivan et al., 2003). But no single gene causes schizophrenia, and stress, heavy cannabis use, and other experiences can raise the risk in people who are vulnerable. On average, people with schizophrenia have somewhat larger fluid-filled ventricles and a slightly smaller hippocampus, though these differences can't diagnose an individual (van Erp et al., 2016).

The **dopamine hypothesis** proposes that too much dopamine activity in certain brain circuits, especially the striatum, makes ordinary things feel strangely important, which may lead to hallucinations and delusions (Howes & Kapur, 2009). Other neurotransmitters, such as glutamate, also play a part.

Treatment and Recovery

Antipsychotic medicines block dopamine D2 receptors (they are antagonists, as you saw in Module 13) and reduce positive symptoms. Older antipsychotics can cause movement problems, and newer ones can cause weight gain, so finding the right medicine takes time. Care works best when medicine is combined with therapy, family education, and help with school and work. In one large U.S. study, people with first-episode psychosis who got this kind of team-based care stayed in treatment longer and had a better quality of life (Kane et al., 2016).

Check Your Understanding

1. Name one positive symptom and one negative symptom of schizophrenia.
2. What does the dopamine hypothesis propose?
3. How do antipsychotic medicines act on dopamine receptors?

The answers are in the unit you just read.

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Unit 14.3: Depression and Bipolar Disorder

Learning Objectives

By the end of this unit, you will be able to:

- Describe major depressive disorder and bipolar disorder, including mania.
- Compare treatments, such as cognitive behavioral therapy, medication, and electroconvulsive therapy.

Feeling down for a day or two is part of life. Depression is different. It can make getting out of bed feel impossible and drain the color out of things you used to love. Bipolar disorder adds periods of unusually high energy and mood.

Major Depressive Disorder

Major depressive disorder involves a depressed mood or a loss of interest or pleasure, most of the day, nearly every day, for at least two weeks, along with other symptoms such as changes in sleep and appetite, low energy, trouble concentrating, feelings of worthlessness, or thoughts of death (APA, 2022). About 7% of U.S. adults have it in a given year, and women are diagnosed about twice as often as men (APA, 2022). Genes account for roughly 40% of the risk (Sullivan et al., 2000).

In the brain, depression is linked to an overactive amygdala, which processes threat and negative emotion, and to lower activity in parts of the prefrontal cortex that help regulate emotion. Long-term stress and the stress hormone cortisol also play a role, as you saw in Module 10. You may have heard that depression is simply a “chemical imbalance” of low serotonin. A large review found little support for that simple idea (Moncrieff et al., 2023). Depression involves many brain systems working differently.

Treatments

Many treatments help. On average, antidepressants such as selective serotonin reuptake inhibitors (SSRIs) work better than a placebo, though they usually take several weeks (Cipriani et al., 2018). **Cognitive behavioral therapy** (CBT), which helps people change unhelpful thoughts and behaviors, works about as well for many people, and the two together often work best.

For severe depression that hasn’t responded, **electroconvulsive therapy** (ECT), given under anesthesia, is one of the most effective treatments (UK ECT Review Group, 2003). Other options include magnetic stimulation of the prefrontal cortex and, since 2019, an esketamine nasal spray given in a clinic (U.S. Food and Drug Administration, 2019).

Bipolar Disorder

Bipolar disorder involves episodes of **mania**, a period of unusually high or irritable mood and energy, often with little need for sleep, racing thoughts, and risky choices. Bipolar I disorder involves at least one manic episode lasting a week or more. Bipolar II disorder involves milder hypomanic episodes and episodes of major depression (APA, 2022). Bipolar disorder is strongly genetic: one twin study estimated heritability at about 85% (McGuffin et al., 2003). Mood stabilizers such as lithium, along with therapy and steady sleep routines, help many people stay well.

Close to Home

Many rural communities, including farmworker communities in the Central Valley, have fewer mental health providers and long drives to care (Morales et al., 2020). Long work hours, cost, and stigma can add to the barriers. Community clinics, telehealth, and trusted community health workers, often called promotoras, help bring care closer to home.

Check Your Understanding

1. How long must symptoms last for a diagnosis of major depressive disorder?
2. What is mania?
3. Which medicine is a common mood stabilizer for bipolar disorder?

The answers are in the unit you just read.

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Unit 14.4: Anxiety and OCD

Learning Objectives

By the end of this unit, you will be able to:

- Describe anxiety disorders and the role of the amygdala.
- Define obsessions and compulsions in obsessive-compulsive disorder (OCD).
- Describe effective treatments.

Your heart pounds before a job interview. That's anxiety doing its job, getting your body ready for a challenge. In an anxiety disorder, that alarm goes off too often, too strongly, or when there is no real danger.

Anxiety Disorders

Anxiety disorders are the most common group of psychological disorders. In one national survey, about 18% of U.S. adults had one in the past year (Kessler et al., 2005). They include generalized anxiety disorder (constant, hard-to-control worry), panic disorder (sudden waves of intense fear with a racing heart and trouble breathing), social anxiety disorder, and specific phobias. Genes explain roughly 30% to 40% of the risk (Hettema et al., 2001).

In brain scans, people with anxiety disorders often show an overactive **amygdala** when they see threatening images (Etkin & Wager, 2007). The prefrontal cortex normally helps calm the amygdala, and in anxiety disorders this braking system may be weaker. GABA (gamma-aminobutyric acid), the brain's main calming neurotransmitter, is the target of benzodiazepines, but because these drugs can cause dependence, they are mainly used for short periods. Selective serotonin reuptake inhibitors (SSRIs) and cognitive behavioral therapy (CBT) are first-choice treatments (Bandelow et al., 2017).

In Plain Words

An anxiety disorder is like a smoke alarm that goes off every time you make toast. The alarm works, but it's set too sensitive. Treatment helps reset it so it saves its loud warning for real fires.

Obsessive-Compulsive Disorder

Obsessive-compulsive disorder (OCD) involves **obsessions**, which are unwanted, intrusive thoughts or urges, such as fear of germs, and **compulsions**, which are repeated actions or mental rituals, such as hand washing or checking, done to ease the distress. About 1% of U.S. adults have OCD in a given year (Ruscio et al., 2010).

OCD is linked to overactivity in a loop connecting the orbitofrontal cortex, the striatum, and the thalamus. The most effective treatments are SSRIs and a type of CBT called exposure and response prevention, in which a person faces a feared situation without doing the ritual (Abramowitz et al., 2009).

From a Peer

"I used to check the stove six or seven times before I could leave. In therapy, I practiced walking away after one check. It was awful at first, but the anxiety faded faster each time."

Check Your Understanding

1. Which brain area is often overactive in anxiety disorders?
2. What is the difference between an obsession and a compulsion?
3. Name one first-choice treatment for anxiety disorders.

The answers are in the unit you just read.

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Unit 14.5: PTSD and Trauma

Learning Objectives

By the end of this unit, you will be able to:

- Describe post-traumatic stress disorder (PTSD).
- Explain how fear circuits in the brain are involved in PTSD.
- Describe treatments that help people heal.

Most people face at least one frightening, life-threatening event in their lives, such as a serious accident, a disaster, violence, or the sudden loss of a loved one. Most people recover. For some, though, the danger stays alive in the mind long after it has passed.

What Is PTSD?

Post-traumatic stress disorder (PTSD) can develop after exposure to actual or threatened death, serious injury, or sexual violence (APA, 2022). Its symptoms fall into four groups: unwanted memories, nightmares, or flashbacks; avoiding reminders; lasting negative changes in thoughts and mood, such as guilt or feeling cut off from others; and being on edge, easily startled, or unable to sleep.

In surveys across 24 countries, about 70% of people reported at least one traumatic event, but PTSD followed only about 4% of these traumatic experiences (Kessler et al., 2017). In the United States, about 6% of adults have PTSD at some point in life (Goldstein et al., 2016). Support from others, coping skills, and the kind of trauma all affect who develops it.

The Brain and PTSD

PTSD involves the same fear circuits you met in Modules 10 and 11. The amygdala tends to be overactive, so reminders set off strong alarm responses, and the prefrontal cortex is less able to calm it (Etkin & Wager, 2007). On average, people with PTSD also have a slightly smaller hippocampus, the area that helps place a memory in its time and place (Logue et al., 2018). That may help explain why a trauma memory can feel like it is happening now instead of in the past.

Healing

PTSD is treatable. Trauma-focused therapies, such as cognitive processing therapy and prolonged exposure, help people safely revisit memories and change the meanings attached to them, and certain antidepressants can also help (American Psychological Association, 2017). Some well-meant approaches don't work. Having everyone talk through an event in a single "debriefing" session right after it happens does not prevent PTSD and may even make things worse for some people (Rose et al., 2002). Researchers are also testing MDMA-assisted therapy, but in 2024 the U.S. Food and Drug Administration (FDA) declined to approve it and asked for more research (Mahase, 2024).

From a Peer

"For years I thought I just had to tough it out. Learning what trauma does to the brain made it easier to ask for help. Healing has been slow, but it's real."

Key Takeaways

- Psychological disorders come from biology, mind, and life experiences working together.
- Schizophrenia, depression, bipolar disorder, anxiety, OCD, and PTSD each involve real changes in brain circuits.

- Effective treatments include medicine, therapy, and support, and many people recover.
- Respectful, person-first language helps reduce stigma and makes it easier to seek help.

Check Your Understanding

1. What kinds of events can lead to PTSD?
2. About what share of people exposed to trauma develop PTSD?
3. Which brain area is often smaller in people with PTSD?

The answers are in the unit you just read.

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Unit 14.6: Module Wrap-Up

You made it through Module 14, the last module in this book. Take a few minutes to look back at what you learned and how it connects to your own life.

You Should Have Learned

- A psychological disorder is a pattern of thoughts, feelings, or behaviors that causes significant distress or makes it hard to function in daily life, and U.S. professionals diagnose these conditions using the DSM-5-TR (14.1).
- The biopsychosocial approach and the diathesis–stress model explain that disorders come from biological, psychological, and social factors working together, as a person's vulnerability combines with life stress (14.1).
- Culture shapes how people experience and describe distress, and the DSM-5-TR includes cultural concepts of distress, such as ataque de nervios (14.1).
- Person-first language, like "a person with schizophrenia," reminds us that a diagnosis is something a person has, not who they are (14.1).
- Schizophrenia involves positive, negative, and disorganized symptoms, is linked to too much dopamine activity in certain brain circuits, and is treated best with medicine combined with therapy, family education, and help with school and work (14.2).
- Major depressive disorder involves a depressed mood or a loss of interest or pleasure for at least two weeks, and antidepressants, cognitive behavioral therapy, or both help many people (14.3).
- Bipolar disorder involves episodes of mania, and mood stabilizers such as lithium, along with therapy and steady sleep routines, help many people stay well (14.3).
- Anxiety disorders, the most common group of psychological disorders, and OCD are linked to overactive brain circuits, and SSRIs and cognitive behavioral therapy, including exposure and response prevention for OCD, are among the most effective treatments (14.4).
- PTSD can develop after a traumatic event and involves an overactive amygdala that the prefrontal cortex is less able to calm, and trauma-focused therapies help people heal (14.5).

Why This Module Matters

Almost everyone knows someone who has lived with depression, anxiety, trauma, or another mental health condition. Maybe it's a friend, a parent, a coworker, or you. Knowing that these are common, real, and often treatable health conditions can make it easier to ask for help and to offer it.

In many rural communities, including farmworker communities in the Central Valley, care can feel far away, but community clinics, telehealth, and promotoras help bring it closer to home. If you or someone you know is struggling, talk with a counselor, health care provider, or mental health staff member you trust, or call or text 988, the Suicide & Crisis Lifeline, any time.

Module 14 ideas in everyday life

Idea	Where you met it	Where you might see it
Person-first language	14.1	Saying "a person with schizophrenia" instead of "a schizophrenic"
Diathesis–stress model	14.1	Understanding why two people can go through the same hard time and respond differently
Anxiety as an alarm	14.4	A smoke alarm set too sensitive, and treatment that helps reset it
Exposure and response prevention	14.4	Practicing walking away after checking the stove only once
Getting care close to home	14.3	Community clinics, telehealth, and promotoras
988 Suicide & Crisis Lifeline	Module 14 introduction	Calling or texting 988 any time, for yourself or someone you're worried about

Reflect

These questions are just for you. There are no right or wrong answers, and nobody else needs to see what you write. You might jot your thoughts in a notebook and keep them as a record of how far you've come.

1. Did this module change how you think about mental health conditions, or about the people who live with them? What changed?
2. Who are the people or places you can turn to when you're struggling? What is one step that would make it easier to reach them?
3. What words about mental health did you grow up hearing? Which would you keep, and which would you like to change?
4. You've reached the end of the book. If you kept notes from earlier Reflect sections, look back at them now. What is one idea about your brain and body that you'll carry with you?

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Unit 14.7: References

About This Module

This new module was written by Michael Miguel for Biological Psychology (Coalinga College Ed.). It draws on Chapter 12, Psychological Disorders, of Biological Psychology by Michael J. Hove and Steven A. Martinez (ROTEL Project, 2024), licensed CC BY-NC-SA 4.0, which adapted material from Psychology 2e by Rose M. Spielman, William J. Jenkins, and Marilyn D. Lovett (OpenStax, 2020), licensed CC BY 4.0, and Fundamentals of Psychological Disorders by Alexis Bridley and Lee W. Daffin Jr. (Washington State University, 2024), licensed CC BY-NC-SA 4.0. It also includes Michael Miguel's earlier unit Epigenetic Mechanisms in Psychological Disorders. Changes: condensed and rewritten in plain, person-first language for Coalinga College campus and Rising Scholars students; treatment information updated; a Central Valley example added; facts checked and corrected. The web addresses below are for reference only; you don't need them to use this book.

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GLOSSARY

#

3Rs | Three guidelines many animal researchers follow: replace animals with other methods when possible, reduce the number of animals used, and refine methods to keep pain and distress as low as possible. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

A

A-delta fibers | Thin, myelinated nerve fibers that quickly carry sharp, first pain and cold signals. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

acetylcholine | A neurotransmitter that tells muscles to move and helps with memory. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

action potential | A brief electrical signal that travels down a neuron's axon when the neuron fires. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

activational effects | Shorter-term effects of hormones that come and go as hormone levels rise and fall, such as at puberty. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

ADME | Short for absorption, distribution, metabolism, and excretion, the four steps of pharmacokinetics. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

adrenal glands | Glands on top of the kidneys that make cortisol and adrenaline, hormones that help the body respond to stress. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

adrenocorticotropic hormone | A hormone released by the pituitary gland that signals the adrenal glands to release cortisol. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

adult neurogenesis | The birth of new neurons in the adult brain, mainly studied in the hippocampus; how much it happens in humans is still debated. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

affective neuroscience | The study of how the brain produces emotions. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

afferent | Carrying signals toward the brain or spinal cord, such as information from the senses. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

aggression | Behavior meant to harm or dominate someone. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

agonist | A drug that fits a receptor and activates it, mimicking or boosting the natural messenger. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

all-or-none | The rule that a neuron either fires a full action potential or doesn't fire at all. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

allodynia | Pain caused by something that normally doesn't hurt, such as a light touch on sunburned skin. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

allostatic load | The total wear and tear on the body from repeated or long-lasting stress responses. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

Alzheimer's disease | A brain disease, and the most common cause of dementia, in which plaques and tangles build up, neurons die, and memory fails. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

amygdala | A small, almond-shaped structure deep in the temporal lobe involved in emotions, especially fear. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

amyloid plaques | Clumps of the protein beta-amyloid that build up between neurons in Alzheimer's disease. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

antagonist | A drug that fits a receptor but blocks it, so the natural messenger can't act. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

anterior | Toward the front. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

anterograde amnesia | The inability to form new memories after a brain injury or illness. [Michael Miguel, adapted from McDermott &

Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

antipsychotic | A medicine that reduces psychotic symptoms, mainly by blocking dopamine D2 receptors. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

anxiety disorders | A group of disorders in which fear or worry is excessive, lasting, and hard to control. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

aphasia | A loss or weakening of language ability caused by brain damage, most often from a stroke. [Michael Miguel, adapted from Kashima (Noba), CC BY-NC-SA 4.0]

apoptosis | Programmed cell death: a planned, tidy way the body removes cells it doesn't need, including extra neurons during development. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

applied research | Research aimed at solving practical, real-world problems using scientific findings. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

arachnoid mater | The middle layer of the meninges, with a web-like look. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

arcuate fasciculus | A bundle of nerve fibers that links Wernicke's area with Broca's area. [Michael Miguel, adapted from Kashima (Noba), CC BY-NC-SA 4.0]

artificial intelligence | Computer systems that do tasks that normally need human thinking, like recognizing faces or understanding language. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

astrocyte | Star-shaped glial cells that bring nutrients to neurons and keep the chemical balance around them steady. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

attenuation model | Treisman's idea that ignored messages are turned down, not blocked, so important words like your name can still be noticed. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

audience design | Adjusting how you speak to fit what your listener already knows. [Michael Miguel, adapted from Kashima (Noba), CC BY-NC-SA 4.0]

audiovisual speech | Understanding speech by combining what you hear with what you see, such as lip movements. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

auditory cortex | The area of the temporal lobe that processes sound. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

auditory nerve | The nerve that carries signals from the hair cells of the cochlea to the brain. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

auditory scene analysis | The brain's process of sorting a mix of sounds into separate sources. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

autonomic nervous system | The part of the peripheral nervous system that runs automatic body functions, such as heartbeat, breathing, and digestion. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

axon | The long part of a neuron that carries messages away from the cell body to other cells. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

B

basal ganglia | A group of structures below the cortex that help control movement and form habits. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

basic research | Research done to expand knowledge and understanding without an immediate practical goal. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

basilar membrane | A membrane running the length of the cochlea that vibrates to sound; different spots respond to different pitches. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

behavioral endocrinology | The study of how hormones affect behavior and how behavior and experience affect hormones. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

behavioral genetics | The study of how genes and environment work together to influence behavior. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

binocular disparity | The small difference between the views of your two eyes, which the brain uses to judge depth. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

biofeedback | A technique that uses sensors to show body signals, such as heart rate or muscle tension, so a person can learn to control them.

[Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

biological psychology | The field that studies how the brain, nervous system, and body influence thoughts, emotions, and behavior. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

biopsychosocial | An approach that explains health and illness through biological, psychological, and social factors working together. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

biopsychosocial model | The view that health depends on biological, psychological, and social factors working together. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

bipolar disorder | A disorder involving episodes of mania or hypomania, usually along with episodes of depression. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

bipolar neuron | A neuron with one dendrite and one axon, found in places like the eye. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

blind spot | The spot on each retina where the optic nerve leaves the eye; it has no photoreceptors, so it can't detect light. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

blindsight | The ability of some people with damage to the primary visual cortex to respond to objects they say they cannot see. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

blood–brain barrier | A protective lining of the brain's blood vessels that keeps many substances, including many drugs, out of the brain. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

brain-computer interface | Technology that allows direct communication between the brain and an outside device to restore or enhance function. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

brainstem | The part of the brain that connects to the spinal cord and controls vital functions such as breathing and heart rate; it includes the midbrain, pons, and medulla. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

Broca's aphasia | Aphasia in which speech is slow and effortful but understanding is fairly well preserved. [Michael Miguel, adapted from Kashima (Noba), CC BY-NC-SA 4.0]

Broca's area | An area in the frontal lobe, usually on the left side, that helps produce speech. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

C

C-fibers | Thin, unmyelinated nerve fibers that slowly carry dull, burning, second pain and warmth signals. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

C-tactile fibers | Slow nerve fibers in hairy skin that respond to gentle, slow stroking and add to the pleasant feeling of touch. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

cannabinoids | Substances, such as THC and CBD, that act on the brain's cannabinoid receptors. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

Cannon–Bard theory | The theory that the brain triggers the body's emotional reaction and the feeling of emotion at the same time. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

cell body | The main part of a neuron, which holds the nucleus and keeps the cell alive. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

central nervous system | The brain and spinal cord. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

cerebellum | A structure at the back of the brain that helps with smooth movement, balance, and learning physical skills. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

cerebral cortex | The thin, wrinkled outer layer of the brain, which handles thinking, planning, language, and sensing. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

cerebrospinal fluid | A clear fluid around and inside the brain and spinal cord that cushions them. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

chemical senses | Taste and smell, the senses that detect chemicals. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

chromosome | A long, tightly packed strand of DNA; most human cells have 46 chromosomes in 23 pairs. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

chronic pain | Pain that lasts or keeps coming back for more than three months. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

chronic traumatic encephalopathy | A brain disease linked to many years of repeated head impacts that can affect memory, mood, and

behavior. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

chunking | Grouping pieces of information into larger, meaningful units so they are easier to remember. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

circadian rhythm | A roughly 24-hour cycle in sleepiness, body temperature, hormones, and other body functions. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

classical conditioning | Learning in which a neutral stimulus comes to trigger a response after being paired with a stimulus that naturally triggers it. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

cochlea | The snail-shaped, fluid-filled part of the inner ear that turns sound vibrations into nerve signals. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

cocktail party effect | The ability to focus on one voice and tune out other sounds in a noisy place. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

cognitive behavioral therapy | A type of therapy that helps people change unhelpful patterns of thinking and behavior. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

cognitive neuroscience | The study of how brain activity supports mental processes like memory, language, and problem-solving. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

common ground | The knowledge, experiences, and assumptions two people share, which lets them communicate with shortcuts. [Michael Miguel, adapted from Kashima (Noba), CC BY-NC-SA 4.0]

comparative psychology | The study of behavior across different species to understand similarities and differences with humans. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

compulsions | Repeated actions or mental rituals done to ease the distress caused by obsessions. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

computerized tomography | A fast brain scan that uses X-rays to show the brain's structure. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

concussion | A mild traumatic brain injury caused by a bump, blow, or jolt to the head. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

conditioned response | The learned response to a conditioned stimulus. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

conditioned stimulus | A once-neutral stimulus that triggers a response after being paired with an unconditioned stimulus. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

conditioned taste aversion | A learned dislike of a food after eating it was followed by illness. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

cones | Photoreceptors that work best in bright light and let you see color and fine detail. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

consciousness | Your awareness of yourself and your surroundings. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

consolidation | The process that makes a new memory stable and lasting. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

contralateral | On the opposite side of the body. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

contrast | The difference in light between nearby spots, which helps you see edges and shapes. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

control group | Participants who do not receive the experimental treatment and serve as a comparison for the experimental group. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

converging evidence | Support for a conclusion that comes from several different research methods pointing to the same answer. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

coping | The thoughts and actions people use to manage stress. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

coronal plane | A slice that divides the brain into front and back parts. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

corpus callosum | A thick band of white matter that connects the left and right hemispheres of the brain. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

corticotropin-releasing hormone | A hormone released by the hypothalamus that starts the HPA axis stress response. [Michael Miguel, adapted

from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

cortisol | A stress hormone made by the adrenal glands that helps the body respond to stress. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

coup | Brain bruising under the point of impact (coup) and on the opposite side of the brain (contrecoup). [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

cranial nerves | Twelve pairs of nerves that come straight out of the brain and serve the head, face, and neck. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

critical period | A window early in life when a missing experience can have effects that are hard or impossible to undo. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

cross-modal plasticity | When a brain area that usually handles one sense starts processing another, such as the visual cortex responding to touch and sound in people born blind. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

crossmodal | When one sense changes what you perceive through another sense, as in the ventriloquism effect. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

cultural concepts of distress | The ways people in a culture experience, understand, and communicate suffering. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

cytochrome P450 | A family of liver enzymes that break down many drugs. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

D

dark adaptation | The slow increase in the eye's sensitivity in the dark as the rods recover, which can take 20 to 30 minutes. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

decibels | The unit used to measure the intensity of sound. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

delusions | Strong false beliefs that a person keeps despite clear evidence against them. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

dementia | A decline in memory and thinking severe enough to interfere with daily life. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

dendrite | Branch-like parts of a neuron that receive messages from other neurons. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

deoxyribonucleic acid | The molecule that carries the genetic instructions for building and running the body. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

dependent variable | The outcome that researchers measure to see whether the independent variable had an effect. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

depressants | Drugs, such as alcohol and benzodiazepines, that slow brain activity. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

depth perception | The ability to see the world in three dimensions and judge how far away things are. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

desirable difficulties | Study conditions that feel harder in the moment but improve long-term learning, such as spacing and self-testing. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

diathesis–stress model | The idea that a disorder develops when a person's vulnerability (diathesis) combines with enough life stress. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

dichotic listening | A research task in which a different message is played to each ear at the same time. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

diffusion tensor imaging | A type of MRI that maps the brain's white matter pathways. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

discriminative stimulus | A cue that signals when a behavior will be reinforced. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

disorganized symptoms | Symptoms of schizophrenia such as speech that jumps between topics and unusual movements or behavior. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

display rules | Unwritten rules in a culture about which emotions are okay to show in a given situation. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

divided attention | Trying to attend to more than one thing at the same time. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

DNA methylation | The attaching of small chemical tags (methyl groups) to DNA, which usually turns a gene off. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

dopamine | A neurotransmitter involved in reward, motivation, and movement. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

dopamine hypothesis | The idea that too much dopamine activity in certain brain circuits contributes to hallucinations and delusions in schizophrenia. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

dorsal | Toward the top of the brain or the back of the body. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

dorsal stream | The “where/how” visual pathway from the visual cortex to the parietal lobe, which tracks location and motion and guides movement. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

double-flash illusion | An illusion in which one flash of light paired with two beeps looks like two flashes. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

drive state | A feeling created by a body need, such as hunger or thirst, that pushes a person to act. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

DSM-5-TR | The Diagnostic and Statistical Manual of Mental Disorders, the guide U.S. professionals use to diagnose psychological disorders. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

dualism | The idea that the mind and the physical body are different kinds of things. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

dura mater | The thick, tough outer layer of the meninges. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

E

eardrum | The thin membrane at the end of the ear canal that vibrates when sound waves hit it. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

early selection | The idea that attention filters information by its physical features before its meaning is processed. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

efferent | Carrying signals away from the brain or spinal cord, such as commands to the muscles. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

electroconvulsive therapy | A treatment for severe depression in which a brief electric current causes a controlled seizure under anesthesia. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

electroencephalography | A method that records the brain’s electrical activity with sensors on the scalp; it shows timing very precisely but location poorly. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

emotion-focused coping | Coping that changes how you feel about a stressor, such as talking to a friend or exercising. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

encoding | Taking in information and turning it into a form the brain can store. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

encoding specificity principle | The principle that retrieval cues work best when they match the conditions present during learning. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

endocrine system | A set of glands that send hormones through the blood to control body functions and influence behavior. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

endorphins | Natural opioid chemicals made by the body that reduce pain. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

engram | The physical trace of a memory in the brain. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

epigenetics | The study of changes in how genes are used that don’t change the DNA sequence itself. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

epigenome | The chemical tags and packaging around DNA that control which genes a cell uses. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

episodic memory | Memory for specific events you experienced. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

eusociality | The highly cooperative social life of animals such as ants and bees, with a division of labor and shared care of young. [Michael

Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

evolutionary perspective | A perspective that asks how natural selection shaped our brains and behavior over many generations. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

evolutionary psychology | The study of how natural selection shaped human behavior and the mind. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

excitatory postsynaptic potential | A small input that pushes a neuron closer to firing. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

experimental group | Participants who receive the treatment or condition being tested in a study. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

explicit memory | Memory you can consciously recall and put into words, including episodic and semantic memory. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

extinction | The fading of a learned response when the conditioned stimulus is no longer followed by the unconditioned stimulus, or a behavior is no longer reinforced. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

F

false memory | Remembering something that did not happen, or remembering it differently from how it happened. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

falsifiability | A quality of a good hypothesis: evidence could show it is wrong. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

fever | A rise in body temperature that happens when the immune system raises the brain's temperature set point. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

fight-or-flight response | The fast stress response of the sympathetic nervous system that prepares the body to fight or escape. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

filter model | Broadbent's early-selection model, in which ignored messages are blocked before their meaning is processed. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

first-pass effect | The breakdown of part of a swallowed drug by the liver before it reaches the rest of the body. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

flashbulb memories | Vivid, confident memories of where you were when you heard shocking news; they are often less accurate than they feel. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

flavor | The combined experience of taste, smell, and touch in the mouth when eating or drinking. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

forebrain | The largest region of the brain, which develops into the cerebrum, thalamus, and hypothalamus. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

forgetting curve | Ebbinghaus's finding that most forgetting happens soon after learning, then slows down. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

fovea | The small center of the retina, packed with cones, that gives the sharpest vision. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

fraternal twins | Twins who develop from two separate fertilized eggs and, like other siblings, share about half of the gene variants that differ between people. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

frequency | How many times a sound wave repeats each second, measured in hertz (Hz); it is heard mainly as pitch. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

frontal lobe | The front part of the cortex, involved in planning, decision-making, movement, and speech. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

functional MRI | A brain scan that tracks changes in oxygen-rich blood flow to show which brain areas are active. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

G

GABA | The brain's main inhibitory neurotransmitter, which calms neural activity. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

gate control theory | The idea that signals in the spinal cord can open or close a "gate" that lets pain signals reach the brain. [Michael Miguel,

adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

gender | The roles, expectations, and identities that a culture builds around sex. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

gender identity | A person's internal sense of being male, female, or something else. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

gene | A stretch of DNA that carries the instructions for making a protein. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

gene expression | The process of using a gene's instructions to make a protein. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

gene–environment interaction | When the effect of a gene depends on the environment, or the effect of an environment depends on a person's genes. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

General Adaptation Syndrome | Selye's model of the body's response to long-lasting stress, in three stages: alarm, resistance, and exhaustion. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

genotype | A person's genetic makeup. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

ghrelin | A hormone made mostly in the stomach that rises before usual mealtimes and helps trigger hunger. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

glial cell | Cells in the nervous system that support and protect neurons but don't send messages the way neurons do. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

glomeruli | Small clusters in the olfactory bulb where signals from the same type of smell receptor come together. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

glucocorticoid receptors | Proteins that detect stress hormones such as cortisol and help switch off the stress response. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

glutamate | The brain's main excitatory neurotransmitter, important for learning and memory. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

Golgi stain | A dye that colors a few whole neurons, branches and all, so they can be seen under a microscope. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

gonads | The ovaries and testes, which make sex hormones such as estrogen and testosterone. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

gray matter | Brain tissue made mostly of neuron cell bodies, where information is processed. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

H

habit | A behavior triggered automatically by cues that continues even when its outcome no longer has value. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

hair cells | Sensory cells in the inner ear with tiny hair-like bundles that turn movement into nerve signals. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

hallucinations | Perceptions without a real outside source, such as hearing voices no one else hears. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

hallucinogens | Drugs, such as LSD and psilocybin, that change perception, mood, and the sense of time. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

head direction cells | Neurons that fire depending on which way the head is facing, like an internal compass. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

heat exhaustion | A heat illness with heavy sweating, dizziness, headache, nausea, and weakness. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

heat stroke | A medical emergency in which body temperature reaches about 104°F or higher and the brain is affected, causing confusion, fainting, or seizures. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

hemorrhagic stroke | A stroke caused by a blood vessel in the brain leaking or bursting. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

heritability | An estimate of how much of the differences between people in a group are linked to differences in their genes. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

high awareness | Deliberately noticing and reflecting on your own thoughts, feelings, and actions. [Michael Miguel, adapted from Biswas-Diener

& Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

hindbrain | The lower region of the brain, which develops into the cerebellum, pons, and medulla. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

hippocampus | A curved structure deep in the temporal lobe that helps form new memories and find your way. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

histone | Spool-like proteins that DNA wraps around inside the cell. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

histone modification | Chemical changes to histones that loosen or tighten how DNA is wrapped, making genes more or less active. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

homeostasis | The body's tendency to keep its inner conditions, such as temperature and water, steady and in a safe range. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

horizontal plane | A slice that divides the brain into upper and lower parts. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

hormone | A chemical messenger that glands release into the blood. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

HPA axis | The hypothalamus–pituitary–adrenal system that releases cortisol in response to stress. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

hunger | The drive state that pushes a person to find and eat food. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

hypnosis | A state of focused, absorbed attention in which people respond more readily to suggestions. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

hypothalamus | A small structure below the thalamus that controls hunger, thirst, body temperature, and hormones through the pituitary gland. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

hypothesis | A testable prediction about the relationship between variables. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

hypovolemic thirst | Thirst caused by a drop in blood volume, such as from bleeding, vomiting, or heavy sweating. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

I

identical twins | Twins who develop from one fertilized egg that splits in two, so they share nearly all of their genes. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

Implicit Association Test | A computer reaction-time test that measures how quickly people pair concepts, used to study automatic associations. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

implicit memory | Memory that shows up in behavior without conscious recall, such as skills, priming, and conditioning. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

inattentional blindness | Failing to notice something obvious because your attention is focused elsewhere. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

independent variable | The factor that researchers change on purpose to see its effect. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

inferior | Toward the bottom. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

informed consent | A written description of what will happen in a study and what the risks are, which studies with people usually require. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

inhibitory postsynaptic potential | A small input that pushes a neuron further away from firing. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

insomnia | Ongoing trouble falling asleep or staying asleep. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

Institutional Animal Care and Use Committee | The ethics review board that must approve animal studies; its members include scientists, veterinarians, administrators, and community members, and it inspects animal facilities twice a year. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

institutional review board | A committee of administrators, scientists, and community members that reviews each study with people before it starts. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

insula | A part of the cortex tucked inside a deep fold that helps you sense your body's inner state and is involved in emotion, pain, and taste. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

interactive alignment | The tendency of conversation partners to start echoing each other's words, phrases, and accents. [Michael Miguel, adapted from Kashima (Noba), CC BY-NC-SA 4.0]

interneuron | Neurons in the brain and spinal cord that connect sensory and motor neurons and process information. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

intersex | Traits present at birth in which physical sex characteristics develop in less typical ways. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

ion | A tiny particle with a positive or negative electrical charge, such as sodium or potassium. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

ipsilateral | On the same side of the body. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

ischemic stroke | A stroke caused by a blockage, such as a blood clot, that cuts off blood flow to part of the brain. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

J

James–Lange theory | The theory that the body reacts first and the feeling of emotion comes from noticing that reaction. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

joint action | Herbert Clark's idea that conversation is something speakers and listeners do together, building meaning as a team. [Michael Miguel, adapted from Kashima (Noba), CC BY-NC-SA 4.0]

L

language | A shared system of sounds, signs, or written symbols, plus rules for combining them, that people use to communicate meaning. [Michael Miguel, adapted from Kashima (Noba), CC BY-NC-SA 4.0]

lateral | Toward the sides. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

lateral geniculate nucleus | The part of the thalamus that relays visual signals from the eyes to the primary visual cortex. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

lateral hypothalamus | A part of the hypothalamus whose damage in early rat studies stopped eating and drinking. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

lateral inhibition | A process in which active cells quiet their neighbors, which makes edges stand out. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

law of effect | Thorndike's principle that behaviors followed by satisfying results become more likely, and those followed by unpleasant results become less likely. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

learning | A lasting change in behavior or knowledge that comes from experience. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

leptin | A hormone made by fat cells that tells the brain how much energy the body has stored. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

lesion | An area of damaged brain tissue. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

liking system | Brain circuits, using the brain's own opioids and endocannabinoids, that produce the pleasure of a reward. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

limbic system | A network of brain structures, including the hippocampus and amygdala, involved in emotion, motivation, and memory. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

localization of function | The idea that specific areas of the brain handle specific jobs. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

long-term memory | The memory store that holds information for days to a lifetime, with no known limit. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

long-term potentiation | A lasting strengthening of a synapse after repeated use, thought to be one way the brain stores learning. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

loudness | How strong or soft a sound seems, which depends mostly on the sound's intensity. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

M

magnetic resonance imaging | A brain scan that uses a strong magnet and radio waves to make detailed pictures of the brain's structure.

[Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

magnetoencephalography | A method that records the tiny magnetic fields made by brain activity; it is fast and more precise in location than EEG. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

major depressive disorder | A disorder with depressed mood or loss of interest, plus other symptoms, nearly every day for at least two weeks. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

mania | A period of unusually high or irritable mood and energy, often with little need for sleep and risky choices. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

McGurk effect | An illusion in which seeing lips say one sound while hearing another makes people hear a third sound. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

mechanoreceptors | Sensory receptors that respond to pressure, stretching, or vibration. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

medial | Toward the middle. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

medial prefrontal cortex | A region in the middle of the frontal lobes involved in thinking about yourself and about other people's thoughts and feelings. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

medial preoptic area | An area of the hypothalamus that is key for maternal care and for male sexual behavior in rodents. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

medulla | The lowest part of the brainstem, which controls heartbeat, breathing, and blood pressure. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

melatonin | A hormone released by the pineal gland in the evening that helps promote sleep. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

memory | The ability to keep and use information over time. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

meninges | Three protective layers of tissue (dura mater, arachnoid mater, and pia mater) that wrap the brain and spinal cord. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

metacognition | Thinking about your own thinking, such as checking what you understand. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

microglia | Glial cells that clean up dead cells and debris in the brain. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

midbrain | The top part of the brainstem, involved in eye movements and quick responses to sights and sounds. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

mindfulness | Paying calm attention to the present moment without judging it. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

mirror therapy | A treatment for phantom limb pain in which a mirror makes the missing limb appear to move normally. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

misinformation effect | When information received after an event changes a person's memory of the event. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

motion sickness | Nausea and discomfort caused by a conflict between what the eyes and the vestibular system sense. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

motion-induced blindness | An illusion in which bright dots seem to disappear when a moving pattern surrounds them. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

motivated forgetting | Forgetting that happens when a person repeatedly pushes an unwanted memory out of mind. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

motor cortex | The strip of cortex at the back of the frontal lobe that controls voluntary movement. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

motor neuron | Neurons that carry commands from the brain and spinal cord to the muscles. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

multimodal | When information from two or more senses combines to help you perceive one event. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

multimodal perception | Combining information from more than one sense into a single experience. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

multipolar neuron | A neuron with one axon and many dendrites; the most common type in the brain. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

mutation | A permanent change in the DNA sequence. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

myelin sheath | A fatty coating around many axons that helps messages travel faster. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

myelination | The wrapping of axons in myelin, which speeds up signals; it continues into early adulthood. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

N

narcolepsy | A sleep disorder with sudden, uncontrollable sleep attacks during the day, linked to the loss of orexin-making neurons. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

natural selection | The process by which traits that help living things survive and have children become more common over generations. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

negative symptoms | Symptoms of schizophrenia that reduce normal behavior, such as less emotion, speech, or motivation. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

nervous system | The network of the brain, spinal cord, and nerves that coordinates sensation, movement, and thought. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

neural tube | The tube of cells that forms in the first month of pregnancy and develops into the brain and spinal cord. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

neurofibrillary tangles | Twisted threads of the protein tau that build up inside neurons in Alzheimer's disease. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

neurogenesis | The birth of new neurons. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

neuron | A nerve cell that sends and receives electrical and chemical messages. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

neuron doctrine | The idea that the nervous system is made of separate cells (neurons) that communicate across tiny gaps. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

neuronal migration | The movement of newly made neurons to their final places in the developing brain. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

neuroplasticity | The brain's ability to change and rewire itself with experience or after injury. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

neuropsychology | The study of how brain injury or illness affects thinking, emotion, and behavior. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

neurotransmitter | A chemical messenger that carries a signal across the synapse from one neuron to the next. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

nociceptors | Sensory receptors that respond to possible tissue damage and can trigger pain. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

node of Ranvier | Small gaps in the myelin along an axon, where the signal is renewed as it jumps along. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

NREM sleep | Non-rapid eye movement sleep, made up of stages N1, N2, and N3 (deep, slow-wave sleep). [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

nucleus accumbens | A brain area involved in motivation, reward, and pleasure. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

nutritional epigenetics | The study of how diet changes which genes are turned on or off. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

O

obsessions | Unwanted, intrusive thoughts, images, or urges that cause distress. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

obsessive-compulsive disorder | A disorder involving unwanted, intrusive thoughts (obsessions) and repeated actions or rituals (compulsions). [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

occipital lobe | The back part of the cortex, which processes vision. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

olfactory bulb | The structure at the front of the brain that receives signals from the smell receptors in the nose. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

olfactory receptor cells | Neurons high in the nose that detect odor molecules. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

oligodendrocyte | Glial cells that make myelin for axons in the brain and spinal cord. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

omnivore's dilemma | The problem omnivores face in choosing safe, nutritious foods from many possible foods. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

omnivores | Animals, including humans, that eat both plants and animals. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

operant conditioning | Learning in which a behavior becomes more or less likely depending on its consequences. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

opioids | Drugs, such as morphine and fentanyl, that act on opioid receptors to relieve pain. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

optic chiasm | The place where the optic nerves meet and some fibers cross to the other side of the brain. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

optic nerve | The nerve that carries visual signals from the eye to the brain. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

optogenetics | A research method, used in animals, that uses light to turn specific neurons on or off. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

orbitofrontal cortex | A part of the frontal lobes just above the eyes that helps judge how pleasant or valuable something is. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

organizational effects | Lasting effects of hormones early in development that shape the body and brain. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

orthonasal olfaction | Smelling odors sniffed in through the nostrils. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

osmotic thirst | Thirst caused by blood that has become too salty, which pulls water out of cells. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

otoconia | Tiny crystals in the otolith organs that shift with gravity and movement and bend the hair cells. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

otolith organs | The utricle and saccule, inner-ear organs that sense head tilt and straight-line movement. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

oxytocin | A hormone made in the hypothalamus that causes contractions in childbirth and milk release in nursing and supports bonding and caregiving. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

P

pair bond | A lasting preference for and attachment to one partner. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

pancreas | A gland that makes insulin and glucagon to control blood sugar. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

papillae | The small bumps on the tongue; many of them hold taste buds. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

parasympathetic nervous system | The branch of the autonomic nervous system that calms the body and saves energy ("rest and digest"). [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

parental behavior | Actions that help offspring survive, such as feeding, protecting, cleaning, comforting, and teaching them. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

parietal lobe | The part of the cortex at the top of the head, behind the frontal lobe, that processes touch, body position, and space. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

peer review | The check a study usually goes through before a scientific journal publishes it, in which several other scientists, usually anonymous, examine its reasoning, methods, ethics, and conclusions and look for flaws. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

perception | The brain's organizing and interpreting of sensory signals into meaningful experiences. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

periaqueductal gray | A midbrain area that helps the brain turn pain down, partly by releasing endorphins. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

peripheral nervous system | All the nerves outside the brain and spinal cord. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

person-first language | Wording that names the person before the condition, such as "a person with schizophrenia." [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

phantom limb pain | Pain that feels as if it comes from a limb that has been amputated. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

pharmacodynamics | The study of what a drug does once it reaches its target, such as a receptor. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

pharmacogenomics | The study of how a person's genes affect their response to drugs. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

pharmacokinetics | The study of how a drug moves through the body: absorption, distribution, metabolism, and excretion. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

phenotype | A person's observable traits, such as height or behavior, which come from genes and environment together. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

pheromones | Chemicals released by one animal that affect the behavior or body of another animal of the same species. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

photoreceptors | Cells in the retina, rods and cones, that turn light into nerve signals. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

pia mater | The thin inner layer of the meninges that hugs the brain and spinal cord. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

pineal gland | A small gland in the brain that makes melatonin, which helps set the sleep-wake cycle. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

pinna | The visible outer part of the ear, which collects sound and helps locate it. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

pitch | How high or low a sound seems, which depends mostly on its frequency. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

pituitary gland | The "master gland" below the hypothalamus that signals other glands and helps control growth, water balance, and reproduction. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

placebo | An inactive treatment, like a sugar pill, used for comparison with an active treatment. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

placebo effect | An improvement caused by a person's belief in a treatment rather than by the treatment itself. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

polypharmacy | Taking several medicines at the same time. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

pons | Part of the brainstem that relays signals between brain areas and helps with sleep and breathing. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

positive symptoms | Symptoms of schizophrenia that add something to experience, such as hallucinations and delusions. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

positron emission tomography | A brain scan that tracks a small amount of injected radioactive tracer to show which brain areas are active. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

post-traumatic stress disorder | A disorder that can follow a traumatic event, with intrusive memories, avoidance, negative mood changes, and being on edge. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

posterior | Toward the back. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

postsynaptic neuron | The neuron that receives a message at a synapse. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

prediction error | The difference between what was expected and what actually happened, which drives learning. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

prefrontal cortex | The front part of the frontal lobe, which handles planning, self-control, and weighing risks; it is one of the last brain areas to mature. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

preparedness | A built-in readiness to learn some associations, such as taste and illness, more easily than others. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

presynaptic neuron | The neuron that sends a message at a synapse. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

primary visual cortex | The first area of the cerebral cortex to process visual signals, located in the occipital lobe; it responds to edges and lines. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

priming | When exposure to one stimulus changes how a person responds to a later stimulus, often without awareness. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

principle of inverse effectiveness | The finding that combining senses helps most when each sense alone gives weak or unclear information. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

proactive interference | When older memories make it harder to learn or recall newer ones. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

problem-focused coping | Coping that changes or removes the stressor itself, such as making a plan or asking for help. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

procedural memory | Memory for skills and habits, such as riding a bike. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

prolactin | A pituitary hormone that triggers milk production and supports parenting behavior. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

proprioception | The sense of where your body parts are and how they are moving, from receptors in muscles and joints. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

psychoactive drug | A substance that changes perception, mood, thinking, or behavior by acting on the nervous system. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

psychological disorder | A pattern of thoughts, feelings, or behaviors that causes significant distress or makes it hard to function in daily life. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

psychoneuroimmunology | The study of how the nervous system, hormones, and immune system interact to affect health. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

psychopharmacology | The study of how drugs affect the brain, mood, and behavior. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

psychophysiology | The study of how bodily signals like heart rate or brain waves relate to mental states. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

punisher | A consequence that makes a behavior less likely. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

R

random assignment | Placing participants into groups by chance to reduce bias and make results more trustworthy. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

receptor | A protein on a neuron where a neurotransmitter attaches to pass on its message. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

reflex | A fast, automatic response, such as pulling your hand off a hot pan, often handled by the spinal cord. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

reinforcer | A consequence that makes a behavior more likely. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

REM sleep | Rapid eye movement sleep, when the brain is very active, most vivid dreams occur, and the body's muscles are temporarily paralyzed. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

renewal | The return of an extinguished response when the cue appears in a different setting. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

replication | Repeating a study to check whether the original findings hold up. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

resilience | The ability to recover and adapt after stress or adversity. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

resting potential | The small negative charge (about –70 millivolts) inside a neuron when it isn't firing. [Michael Miguel, adapted from Hove

& Martinez, CC BY-NC-SA 4.0]

retina | The thin layer of tissue lining the back of the eye that contains the photoreceptors. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

retrieval | Bringing stored information back into awareness. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

retrieval cues | Reminders that help bring a memory back. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

retroactive interference | When newer learning makes it harder to recall older memories. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

retrograde amnesia | Loss of memories formed before a brain injury or illness. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

retronasal olfaction | Smelling odors that travel from the mouth up the back of the throat to the nose while eating. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

reuptake | The process in which the sending neuron takes neurotransmitters back in after they are released. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

reuptake inhibitor | A drug that blocks the recycling of a neurotransmitter, so more of it stays in the synapse. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

rods | Photoreceptors that work best in dim light and detect shades of gray. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

route of administration | The way a drug enters the body, such as by swallowing, inhaling, injecting, or a skin patch. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

rubber hand illusion | An illusion in which seeing a fake hand stroked at the same time as your hidden hand makes the fake hand feel like your own. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

S

sagittal plane | A slice that divides the brain into left and right parts. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

saltatory conduction | The way a signal jumps from one node of Ranvier to the next along a myelinated axon. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

satiety | The feeling of fullness that ends a meal. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

schizophrenia | A disorder involving major changes in thinking, perception, emotion, and behavior, such as hallucinations and delusions. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

Schwann cell | Glial cells that make myelin for nerves outside the brain and spinal cord. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

scientific method | A step-by-step process of asking questions, forming hypotheses, testing them, and drawing conclusions from evidence. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

selective attention | Focusing on one thing while ignoring others. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

self-efficacy | The belief that you can handle a task or challenge. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

semantic memory | General knowledge of facts and meanings. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

semicircular canals | Three fluid-filled loops in the inner ear that sense turning movements of the head. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

sensation | The detection of energy, such as light or sound, by the sense organs. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

sensitive period | A time when experience has an especially strong effect on the brain, though learning is still possible later. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

sensitization | An increase in the response to a stimulus, such as stronger pain after an injury. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

sensory memory | A very brief, detailed copy of what was just seen or heard. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

sensory neuron | Neurons that carry information from the senses toward the brain and spinal cord. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

serotonin | A neurotransmitter involved in mood, sleep, and appetite. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

set point | The target level, such as a body temperature near 98.6°F, that the body works to maintain. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

sex | Biological traits, such as chromosomes, hormones, and reproductive organs, that are used to classify a person as female, male, or intersex. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

sexual arousal | A drive state of heightened sexual interest and readiness, triggered by hormones, thoughts, and outside cues. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

sexual dimorphism | Physical or behavioral differences between the sexes of a species. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

shadowing | Repeating aloud one message while ignoring another, a task used in dichotic listening studies. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

shaping | Reinforcing closer and closer steps toward a goal behavior. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

short-term memory | The memory store that holds a small amount of information for about 15 to 30 seconds unless it is rehearsed. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

sleep apnea | A sleep disorder in which breathing repeatedly stops during sleep, often with loud snoring. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

sleep disorders | Conditions that disrupt the amount, timing, or quality of sleep, such as insomnia, sleep apnea, and narcolepsy. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

smell | The sense that detects odor molecules in the air; also called olfaction. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

social categorization | Automatically sorting people into groups, such as by age, gender, or race. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

social neuroscience | The study of how the brain and body support social thoughts, feelings, and behavior. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

sodium-potassium pump | A protein that keeps a neuron ready to fire by moving sodium out of the cell and potassium in. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

somatic nervous system | The part of the peripheral nervous system that controls voluntary movement and carries information from the senses. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

somatosensory cortex | The strip of cortex at the front of the parietal lobe that processes touch and other body sensations. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

somatosensory system | The body senses: touch, temperature, pain, and the sense of body position. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

spacing effect | Better long-term memory when study is spread over several sessions rather than crammed into one. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

spatial resolution | How precisely a method can show where something happens in the brain. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

spinal cord | The bundle of nerve tissue in the spine that carries signals between the brain and body and handles reflexes. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

spinal nerves | Thirty-one pairs of nerves that branch off the spinal cord and carry both sensory and motor signals. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

spontaneous recovery | The return of an extinguished response after time passes. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

SRY | A gene on the Y chromosome that makes a protein that starts the processes that lead a fetus to develop testes. [Michael Miguel, Biological Psychology (Coalinga College Ed.), CC BY-NC-SA 4.0]

stimulants | Drugs, such as caffeine, nicotine, and amphetamines, that raise alertness and energy. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

stimulus control | When a behavior happens mainly in the presence of a cue that signals it will be reinforced. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

storage | Keeping information in memory over time. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

stressor | Anything that threatens or challenges a person's well-being. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

stroke | An injury caused when blood flow to part of the brain is interrupted. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

substance use disorder | Continued use of a substance despite harm, with craving and loss of control; the medical term for addiction. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

summation | Adding up all the excitatory and inhibitory inputs a neuron receives to decide whether it fires. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

superadditive effect | When the response to two senses together is greater than the sum of the responses to each sense alone. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

superior | Toward the top. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

superior colliculus | A midbrain structure that combines sight and sound and quickly turns the eyes and head toward sudden events. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

suprachiasmatic nucleus | A small cluster of neurons in the hypothalamus that acts as the body's master clock. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

sustained attention | Keeping focus on one task over a long period. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

sympathetic nervous system | The branch of the autonomic nervous system that gets the body ready to act ("fight or flight"). [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

synapse | The connection point where one neuron passes a message to another. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

synaptic cleft | The tiny gap between the sending and receiving neurons at a synapse. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

synaptic pruning | The removal of unused synapses, which makes the remaining connections more efficient. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

synaptic vesicle | Small packets inside the terminal buttons that hold neurotransmitters. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

synesthesia | A condition in which stimulating one sense automatically triggers an experience in another, such as seeing letters in color. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

T

task switching | Shifting attention back and forth between tasks, which costs time and causes errors. [Michael Miguel, adapted from Biswas-Diener & Teeny, Paller & Suzuki, and Friedrich (Noba), CC BY-NC-SA 4.0]

taste | The sense that detects sweet, salty, sour, bitter, and umami chemicals in the mouth. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

taste buds | Clusters of taste receptor cells, mostly found in the papillae of the tongue. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

temporal lobe | The part of the cortex on the side of the head that processes sound, language understanding, and memory. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

temporal resolution | How precisely a method can show when something happens in the brain. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

tend and befriend | A response to stress that involves protecting loved ones and reaching out to others for support. [Michael Miguel, adapted from Nelson; Carter & Porges; and Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

terminal button | Small knobs at the end of an axon that release neurotransmitters. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

testing effect | Better long-term memory from practicing recall, such as self-quizzing, than from rereading. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

thalamus | A relay hub in the middle of the brain that passes sensory information to the cortex. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

theory | A well-supported explanation that ties findings together and predicts future results. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

thermoreceptors | Sensory receptors that respond to warmth or cold. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

threshold | The level of charge (about –55 millivolts) a neuron must reach to fire an action potential. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

thyroid gland | A gland in the neck that sets the pace of metabolism. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

timbre | The quality that makes two sounds with the same pitch and loudness sound different, such as a guitar and a piano. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

tolerance | Needing more of a drug to get the same effect after repeated use. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

tonotopic organization | An arrangement in which neighboring places respond to neighboring pitches, from the cochlea to the auditory cortex. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

transcranial direct current stimulation | A method that sends a weak electrical current through the scalp to change brain activity. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

transcranial magnetic stimulation | A noninvasive method that uses magnetic pulses to stimulate the brain, used to study and treat conditions like depression. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

transfer-appropriate processing | The principle that memory is best when the way you study matches the way you will use the information. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

traumatic brain injury | Brain damage caused by an outside force, such as a blow to the head. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

two-factor theory | Schachter and Singer's theory that emotion comes from body arousal plus the label we give it based on the situation. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

Type A behavior pattern | A competitive, impatient, and hostile style; its hostility is linked to a higher risk of heart disease. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

U

unconditioned response | A natural, unlearned response to an unconditioned stimulus. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

unconditioned stimulus | A stimulus that naturally triggers a response without learning. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

unipolar neuron | A neuron with a single extension, the shape of many sensory neurons for touch and temperature. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

V

valley fever | An infection caused by breathing in spores of a fungus that lives in soil in the Central Valley and other dry parts of the Southwest; it usually affects the lungs and rarely spreads to the brain. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

vasopressin | A hormone made in the hypothalamus that tells the kidneys to save water and also plays a role in social memory and pair bonding. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

ventral | Toward the bottom of the brain or the belly side of the body. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

ventral pallidum | A small brain area that works with the nucleus accumbens to produce the pleasure of rewards. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

ventral stream | The "what" visual pathway from the visual cortex to the temporal lobe, which helps recognize objects, faces, places, and words. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

ventriloquism effect | An illusion in which a sound seems to come from a moving mouth you see, such as a puppet's, instead of its real source. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

ventromedial hypothalamus | A part of the hypothalamus involved in ending meals and, in female rodents, in readiness to mate; damage to it in early rat studies led to overeating. [Michael Miguel, adapted from Bhatia & Loewenstein (Noba), CC BY-NC-SA 4.0]

vestibular system | The inner-ear system that senses head movement and position and helps keep balance. [Michael Miguel, adapted from Oxenham; Bartoshuk & Snyder; Løseth, Ellingsen & Leknes; and Angelaki & Dickman (Noba), CC BY-NC-SA 4.0]

vestibulo-ocular reflex | An automatic eye movement that moves the eyes opposite to head movement to keep vision steady. [Michael Miguel, adapted from Buetti & Lleras and Lachs (Noba), CC BY-NC-SA 4.0]

W

wanting system | Dopamine-driven brain circuits that create desire and push us to seek rewards. [Michael Miguel, adapted from Ito & Kubota, Harmon-Jones & Harmon-Jones, and Hooker & Pressman (Noba), CC BY-NC-SA 4.0]

WEIRD | Short for Western, Educated, Industrialized, Rich, and Democratic: the kinds of societies most psychology research participants come from. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

Wernicke's aphasia | Aphasia in which speech is fluent but often makes little sense and understanding is poor. [Michael Miguel, adapted from Kashima (Noba), CC BY-NC-SA 4.0]

Wernicke's area | An area in the temporal lobe, usually on the left side, that helps understand speech. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

white matter | Brain tissue made mostly of myelinated axons that connect different brain areas. [Michael Miguel, adapted from Hove & Martinez, CC BY-NC-SA 4.0]

withdrawal | Uncomfortable or dangerous symptoms that appear when a person stops using a drug the body has adapted to. [Michael Miguel, adapted from Hove & Martinez (ROTEL), CC BY-NC-SA 4.0]

working memory | The system that briefly holds and works with information you are thinking about right now. [Michael Miguel, adapted from McDermott & Roediger, Bouton, Dudukovic & Kuhl, and Benjamin (Noba), CC BY-NC-SA 4.0]

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