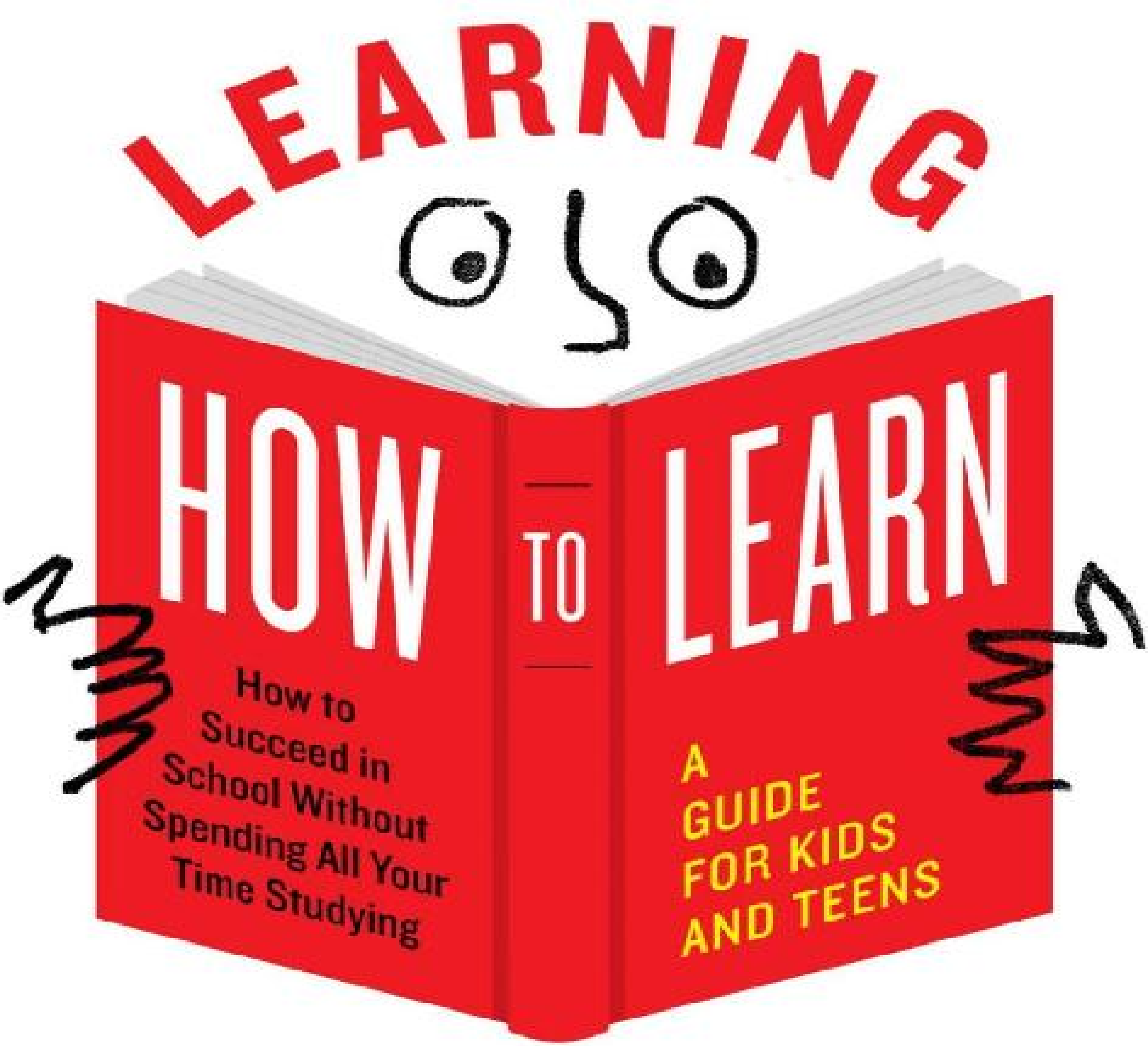
From the bestselling author of *A Mind for Numbers* and the creators of the popular online course Learning How to Learn



LEARNING HOW TO LEARN

How to Succeed in School Without Spending All Your Time Studying

A Guide for Kids and Teens

BARBARA OAKLEY, PhD, AND
TERRENCE SEJNOWSKI, PhD,
WITH ALISTAIR McCONVILLE

Advance Praise for *LEARNING HOW TO LEARN*

“The authors’ neuroscience-grounded, yet real-life, approach will be of value to learners of any age.”

— Adam Gazzaley, MD, PhD, Professor in Neurology, Physiology, and Psychiatry at the University of California, San Francisco

“In this highly readable and lively book, the authors illustrate how the brain and behavioral dynamics underlie effective learning—and they do so in a way that young learners will find understandable and even entertaining.”

— Robert A. Bjork, Distinguished Research Professor of Psychology at the University of California, Los Angeles

“*Learning How to Learn* shows kids and teens that a little knowledge of how their brain works goes a long way in helping them improve their learning and studying success. This unique book is full of fun learning strategies—I highly recommend it!”

— Paula Tallal, PhD, Board of Governors Professor Emeritus of Neuroscience at Rutgers University and cofounder of Scientific Learning Corporation

“I devoured *Learning How to Learn* in three sittings (I needed time for diffuse thinking, active recall, and sleep). A terrific book!”

—Jeff Sandefer, cofounder of Acton School of Business

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BARBARA OAKLEY, PhD,
and TERRENCE SEJNOWSKI, PhD

with ALISTAIR McCONVILLE

with illustrations by OLIVER YOUNG

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A NOTE TO PARENTS AND TEACHERS

Welcome to our book. You're helping a younger person to learn more effectively, which means we're already on the same team!

Some of the ideas in this book were discussed in Barb's bestselling *A Mind for Numbers*. Many readers felt that the ideas were so simple, and so practically useful, that they should be shared with younger audiences. And we have heard from thousands of people that these ideas are useful for learning all subjects, not just math.

So this book is intended for tweens and teens—although adults will also find a treasure trove of new and practical ideas here. Understanding just a little bit about how the brain works can make learning more fun and less frustrating.

There are several ways to use this book. Some young adults may wish to read it on their own. They can talk with their friends about the key ideas to help cement them in their minds. Some young adults (and adults!) may be tempted to skim through the book, thinking they'll get everything if they just read from cover to cover. Nothing could be further from the truth! Active involvement is key—the exercises are helpful only if they are completed. The book is best read with a notebook at the side, to take notes, answer questions, and make doodles with key insights. With young "skimmers," the more an adult can dip in, question, and interact, the more will be gained.

If you are a parent or grandparent, aunt or uncle, we suggest that your young person might read the book out loud to you. Generally, a half hour of reading at a stretch is a good length. (Younger children may read for a shorter time.) Reading aloud is a fun adventure where you can learn together, as a family.

If you are a teacher, you may wish to read the book together with your students. Or you may have a silent reading period, followed by a shared discussion. You will find that this book gives you a shared vocabulary to help you teach other subjects.

Younger is better when it comes to learning about learning, as it allows for more years to use the tools. It also opens doors for the great new careers that are emerging with modern-day changes.

Thanks for joining us on this learning adventure. Let’s dive in!

—Barb Oakley, Terry Sejnowski, and Al McConville

CHAPTER 1

THE PROBLEM WITH PASSION

Hi, my name's Barb. Great to meet you!

I have a secret. When I was growing up, I was sometimes a terrible student. Sure, I was fine in subjects I liked. But otherwise, forget it.

Everybody told me to follow my passion. I figured that meant, *Do what you like, not what you don't like*. That sounded like good advice to me. I *hated* math and science, so I avoided those subjects as if they were poison. When I had to take those courses, I did badly, or I just plain failed.

I'm now a professor of engineering. Surprised? Engineers *need* a deep knowledge of math and science. I'm now really good at math and science, and I love them. How did I do it? I discovered the secrets of learning well.

This is a picture of me—Barb Oakley. I learned that I could learn much more than I'd ever thought I could.

This is a book about how to become a successful learner. It's written for tweens and teens, but the lessons in it apply to everyone. And they relate to all kinds of learning. Whether you are interested in soccer (better known as football around the world!), math, dance, chemistry, riding a unicycle, learning another language, getting better at video games, or understanding the physics of how a ball bounces, this book is for you.

Brains are amazing. They're the most sophisticated gadgets in the universe. They change their structure depending on what you do with them.

Pretty much anyone can do well in any subject if they know more about learning. Your brain is more powerful than you think. You just need to know how to turn on that power. There are simple tricks that can improve your learning whether you're already a good student—or not so good. These tricks can also make your learning more fun. (For example, you're going to meet a few zombies in this book, but don't worry, they're mostly friendly ones who want to help you learn!)

I wrote this book with Professor Terry Sejnowski. Terry knows a lot about brain science—that is, "neuroscience."* Terry's an expert when it comes to learning. He works with other neuroscientists who are helping us to learn better. Professors from other areas like psychology* and education are also discovering a lot about how we learn.

Here's my coauthor Terrence Sejnowski. He's an expert on the brain.

Terry and I want to share lessons from all of these areas. We want to help improve your ability to learn. The lessons backed by science in this book are coming from both Terry and me. Alistair McConville is also an important part of our author team. He has many years of experience teaching young people, so he helped us make our writing less formal and easier to understand.

Here's our other coauthor, Alistair McConville. Al has worked with teens for years!

Terry and I *know* it's possible to improve your learning abilities. How do we know? We teach the largest "massive open online course" ("MOOC") in the world. It's called Learning How to Learn. We have had millions of students. Through this course, we have seen all sorts of people make big improvements in their learning skills. It's not a surprise that the course helps. It's based on the best of what we know from research about how we learn. So we know it works!

Even great students can improve their ability to learn. So can those who are not there yet. The techniques and lessons we're going to teach you won't necessarily make learning super easy. But they will leave you with more time to do the things you like, whether it's video games, soccer, watching YouTube, or just hanging out with friends. In fact, you can use these ideas to *improve* your ability to play soccer and video games!

Learning how to learn will make your years in school more fun and less frustrating. We'll give you powerful tools to improve your memory, to get your work done more quickly, and to help you become an expert at whatever subjects you choose. You'll discover fantastic and inspiring insights. For example, if learning is slow and hard for you, you actually have special advantages in the creativity department.

Learning *how* to learn does something more, though. It opens whole horizons for your future. The working world of the future needs creative people who have many different talents. We're here to help you develop the many talents, and the creativity, that lie within you!

Jump Ahead If You'd Like!

If you want to get straight to the tips on how best to learn, jump now to the "Now You Try!" section at the end of this chapter. But if you'd like to learn more about Barb's past, and how she changed her brain to learn better, keep reading. (You'll get to go with her to the South Pole in Antarctica.)

Later, you'll have a chance to hear Terry's and Al's stories—you'll see how different we all are.

How I Changed My Brain

When I was young, I loved animals and handicrafts, but not numbers. I hated them. For example, I was confused by old-fashioned clocks. Why was the hour hand smaller than the minute hand? Weren't hours more important than minutes? So why wasn't the hour hand the biggest? Why were clocks so confusing?

Me at age ten with Earl the lamb. I loved critters, reading, and dreaming. Math and science weren't on my playlist.

Technology was not my friend, either. I couldn't figure out all the buttons on the TV (this was in the days before remote controls). This meant I only watched TV shows when my brother or sister handled the "technical" side of things. So I didn't feel too good about my chances in subjects like math and science.

Some bad luck at home made things worse. When I was thirteen, my father lost his job because of a back injury, and we had to move. In fact, I moved a lot while I was growing up. By the time I was fifteen years old I had lived in ten different places. Each time I started a new school, I had missed a different piece of math. I felt lost. It was like picking up a book and discovering that the chapters were all out of order. It made no sense to me.

I lost all interest in math. I almost took pride in being terrible at it. It was just "who I was." I thought of numbers and equations as deadly diseases—to be avoided at all costs.

I didn't like science, either. In my first chemistry experiment, my teacher gave my partner and me a different substance from the rest of the class. He made fun of us when we tried to make our results match everyone else's.

Luckily, I was better at other subjects. I liked history, social studies, and anything cultural. My grades in these classes helped me to graduate from high school.

Since I didn't get along with numbers, I decided to learn a foreign language. I had grown up around people who spoke only English. It seemed so exotic to be able to speak two languages. But I couldn't afford to go to college. What could I do?

I found out that the military would pay me to learn a new language. So, right out of high school, I joined the army to learn Russian. Why Russian? No particular reason. It just looked interesting.

I studied at the Defense Language Institute in California. They knew the best techniques for teaching a language. Learning a new language didn't come easily for me. I didn't have a good memory, so I had to practice a lot. But gradually, I got better.

I ended up doing well enough that I earned a scholarship (free money for school) to go to a regular, full-scale university. There, I continued to study Russian. I was so excited! I'd followed my passion for learning a new language, and it was paying off for me.

Except.

Disaster Strikes

The military made me an officer in a group called the Signal Corps. This meant I would be working with my old enemy, technology. Radios, cables, and telephones . . . I went from being a language expert to feeling like I was back in my high school chemistry class. I was lost.

Then I was sent to Germany to manage a group of fifty soldiers specializing in communications. More technology. I turned out to be terrible at my job. If *I* couldn't set up the communications gear, how could I tell the soldiers how to do it?

The officers working around me with their own groups were very successful. They were engineers, so they were comfortable with technology, math, and science.

At twenty-six, I left the military. Few people wanted to hire me. My language skills were great, but I didn't have any other skills that would help me get a job. I realized that by only following my passion, I didn't have many choices.

Language and culture will always be important. But today, science, math, and technology are also important. I wanted some of the exciting new opportunities these areas offered! But I'd have to retrain my brain to learn math and science to have a chance. Was that even possible for someone like me?

I decided to try.

Rebuilding My Career

I headed back to university to study engineering. I started at the lowest possible level of math—algebra for people who had failed it in high school.

At first, I felt like I was blindfolded. Other students found solutions to problems easily when I didn't. During those first months, I wondered if I'd made the right decision.

If only I'd known then what I know now, it would have been so much easier. Of course, that's what this book is about. We want to share the best mental learning tools, so you don't struggle like I did.

After a few years of college, my career chances improved. I still used my language skills. For example, I worked as a translator on a Russian fishing boat. But I also began to use my new technical skills. I even ended up working as a radio operator at the South Pole Station.

My husband, Phil Oakley, in Antarctica after 10 minutes outside at -70° Fahrenheit. He's my hero!

By the way, the South Pole Station is where I met my husband, Phil. Here he is after just ten minutes at minus seventy degrees in a wild wind. I had to go to the end of the earth to meet that man! If I hadn't learned how to learn math and science, I never would have met him. We've now been married for nearly thirty-five years. (You'll meet one of our children later.)

Eventually, I graduated with a new degree in electrical engineering. After working for four years as an engineer, I went back to school to get a master's degree in electrical and computer engineering. Then, with several more years of study, I got a degree called a "doctorate" in systems engineering. That's why people sometimes call me "Doctor" Oakley. (But I still prefer "Barb.") I became an expert at complex mathematical equations and scientific concepts. All this from the girl who couldn't work the TV.

I had "rewired" my brain so that I could overcome my weaknesses.

As a professor, I'm now really interested in how people learn. That's how I got to know my coauthor, Terry Sejnowski. We talked a lot with each other about how people learn. And that's how I got to meet our other coauthor, Alistair ("Al") McConville. He has learned how to learn in an unusual way.

We want to share lessons about how *your* brain learns best. These techniques are simple. Lots of talented adults have told us they wish they'd had these easy-to-understand tools when they were younger—it would have made their learning so much easier. It would even have changed the direction of their learning. They didn't realize the power they had within them.

You have a special gift for learning. When you unleash it while you are still young, you will enjoy its effects throughout your life.

It's easy to believe that you should only concentrate on subjects that come easily for you. But my story reveals that you can do well in subjects you don't even like. The truth is, it's okay to follow your passions. But I also found that *broadening* my passions opened many wonderful opportunities. Learning new subjects I didn't think I could do turned out to be an adventure!

People find it hard to believe they can be successful learners if they have trouble with a subject. But neuroscience (that's "brain science") shows that they're wrong. Your brain is like an incredible tool kit. Your job is to learn when, and how, to use those tools. After all, you wouldn't use a hammer to turn a screw.

Anyway, that's enough about me and why Terry, Al, and I have written this book. In the next chapter, I'll show you what's happening when your learning becomes frustrating. There is a simple trick to make your learning easier and happier.

Now You Try! Do a Picture Walk!

I used to go through my textbook page by page. I was trying to make sure I understood all the ideas before I turned the page. Sounds sensible, right?

Don't do this! It was a big mistake.

Instead, when you start a new chapter, go on a "picture walk"* through it. Scan it. Look briefly at all the pictures, captions, and diagrams, but also at the section headings, bold words, and summary, and even questions at the end of the chapter, if the book has them.

It's important to do a "picture walk" through the book to see the pictures and the section headings before you begin reading.

This might seem crazy. You haven't read the chapter properly yet. But you're giving your brain an idea of what's coming. It's a little like watching a preview of a movie, or checking a map before you set off on a journey. You'll be surprised at how spending a minute or two glancing ahead before you read in depth will allow you to organize your thoughts. This works even if you read on an electronic device. Just bookmark the beginning of the chapter so you can easily return to it.

It's a little like a closet. The picture walk gives you "hangers" where you can organize the information you're reading. Without hangers, the clothes just fall on the floor in a jumble.

Important! Get out a notebook or a piece of paper—as you read the next chapter, take notes, answer questions, and make doodles with key insights. This will help you avoid mindless reading and help glue the new ideas into your brain. Of course, before you begin to read the chapter, be sure to do a picture walk. And try to answer some of the end-of-chapter questions so you have a sense of what you're aiming at in your learning.

If you make a habit of this for each chapter, you will find the book’s ideas will be much more powerful in helping you!

CHAPTER 2

EASY DOES IT

Why Trying Too Hard Can Sometimes Be Part of the Problem

Has your teacher, or your mom or dad, ever told you to *pay attention*? Or to *focus*? You've probably told *yourself* to do it! That's because it's easy to become distracted. Sometimes whatever is going on outside the window seems more interesting than what's right in front of you. You can't help but think ahead to things like friends, or lunch.

Getting distracted is always bad. Right?

Maybe not. Let's see.

Take a look at the chess game in the following picture. Look at the boy on the left. He's playing against the guy on the right. The boy's rude, isn't he? Typical thirteen-year-old. No concentration. (Ever heard adults say things like that? They usually blame it on smartphones.)

Thirteen-year-old Magnus Carlsen (left) and legendary chess genius Garry Kasparov playing speed chess at the "Reykjavik Rapid" in 2004. Kasparov was surprised that Magnus wandered off, looking at other games. Garry Kasparov is one of the greatest chess players of all time. Magnus is not concentrating, so he must have no chance of winning. Right?

Amazingly, Kasparov didn't win the chess match. It was a tie. The world's best chess player couldn't defeat what appeared to be a hopelessly distracted thirteen-year-old.

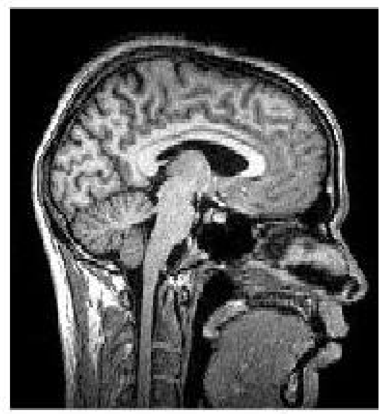
Surprise! *Sometimes we need to lose concentration so we can think more clearly.* Zoning out occasionally (not all the time) can be useful when you're learning or problem solving.

Soon after this photo was taken, Magnus returned to the table and focused on the game again. He had taken a little break so he could focus better when he returned.

The message of this chapter is that *sometimes* you need to be *less* focused in order to become a better learner. How can that be?

You’ve Got Two Ways of Thinking!

In the last chapter, I mentioned the word “neuroscience”—the science of the brain. Neuroscientists use new brain-scanning technology to look inside the brain and understand it better.



On the left, brain-scanning workers are looking through the scanner. People lie on a special bed that slides into the scanner. The scanner is then able to take a picture of the inside of their brain, like the one on the right. Pretty neat!

Neuroscientists have discovered that your brain works in two different ways. We’ll call these two ways of working the *focused* mode and the *diffuse* mode.* *Both* modes are important in helping you to learn.

Focused Mode

When you're using your focused mode, it means that you're paying attention. For example, you might be trying to figure out a math problem. Or you might be looking at and listening to your teacher. You focus when you're playing a video game, putting together a puzzle, or learning words from a different language.

When you're focusing, you're putting specific parts of the brain to work. Which parts are working depends on what you're doing. For example, when you're doing multiplication problems, focusing will use different parts of the brain than when you're speaking.*[1] **When you are trying to learn something new, you must first focus intently on it in order to "turn on" those parts of the brain and get the learning process started.**

When you're in focused mode, you're paying close attention.

Diffuse Mode

If that's *focused* mode, what is *diffuse* mode?

Diffuse mode is when your mind is relaxed and free. You're thinking about nothing in particular. You're in diffuse mode when you're daydreaming or doodling just for fun. If your teacher tells you to *concentrate*, you have probably slipped into diffuse mode.

In diffuse mode, you're not thinking about anything in particular.

When you're in diffuse mode, you're gently using other parts of the brain that are mostly different from the parts you use when you are focusing. The diffuse mode helps you make imaginative connections between ideas. Creativity often seems to pop out of using the diffuse mode.

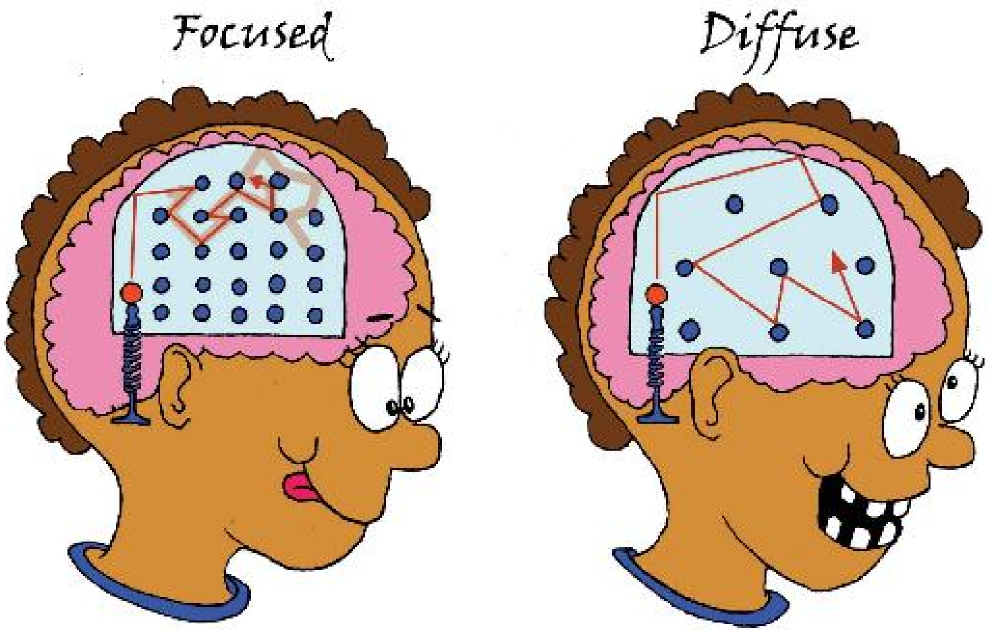
It turns out that your brain has to go back and forth between focused and diffuse modes in order to learn effectively.

Let’s Play Pinball

To better understand focused and diffuse modes, let’s turn to a game called pinball. It’s easy to play. You just pull back on a plunger. Once you let the plunger go, it hits a ball up onto a table. You score points as the ball bounces around on the rubber bumpers. Meanwhile, flashing lights and wacky sounds go off. You use the flippers on the lower portion of the table to keep the ball up and bouncing as long as possible.

Pinball tables are kind of like your brain. Their bumpers can be closer or farther apart depending on the table. When the bumpers are close together, it’s like your brain in focused mode. The ball bounces around rapidly in one small area before running out of energy and falling down.

Imagine that your mental ball leaves a trail when it travels. That’s like your focused mode—you make trails in your brain when you’re focused. These trails are laid when you first learn something and begin to practice using it. For example, let’s say you already know multiplication. If I asked you to work a multiplication problem, your thoughts would move along the same “multiplication trails” that had already been laid in your brain. To see what I mean, take a look at these pictures.



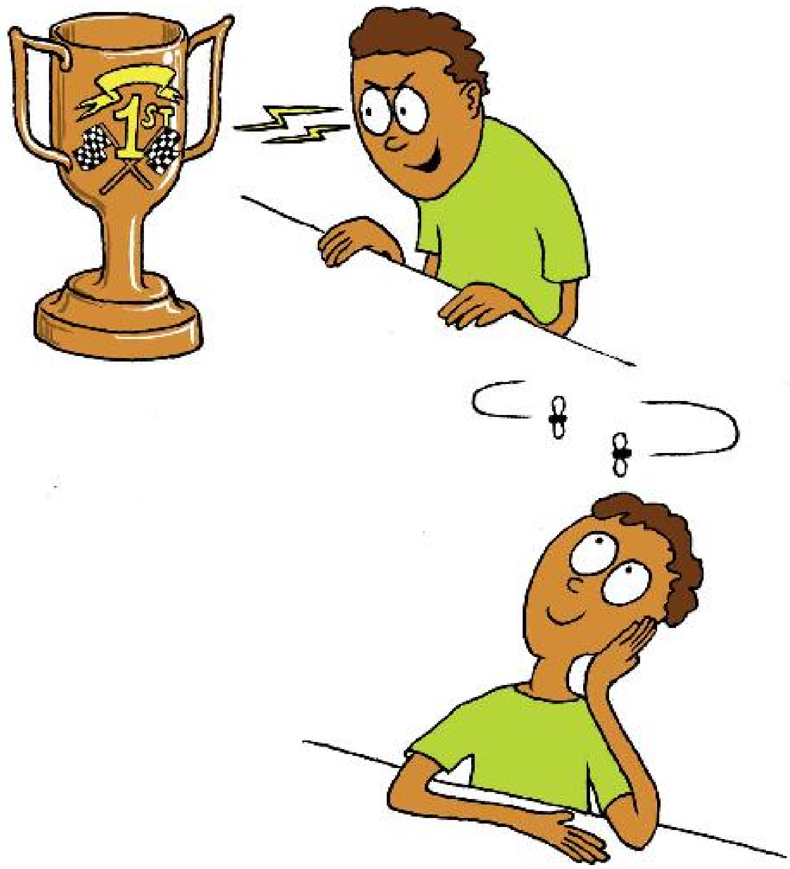
On the left is the pinball version of the brain in focused mode. See how close together the rubber bumpers are? The ball moves in a tight pattern. Your thoughts can't go very far! The ball is following a fuzzy pattern that has already been laid because you've had the thought before. On the right is a pinball version of the brain in diffuse mode. Notice how widely your thoughts can range in your brain!

The diffuse mode is different. In this mode, the table's bumpers are much farther apart. The thought-ball travels much more broadly around the table, hitting fewer bumpers.

Our brains act like *both* kinds of pinball machine. If we want to shift from thinking about the details to thinking freely about the bigger picture, we have to shift from focused to diffuse mode. You need two tables. (But importantly, your brain can be in only *one* mode at a time. The zombie can't play with two machines at once!)

Here's a fun way to get a sense of the difference between the two modes:

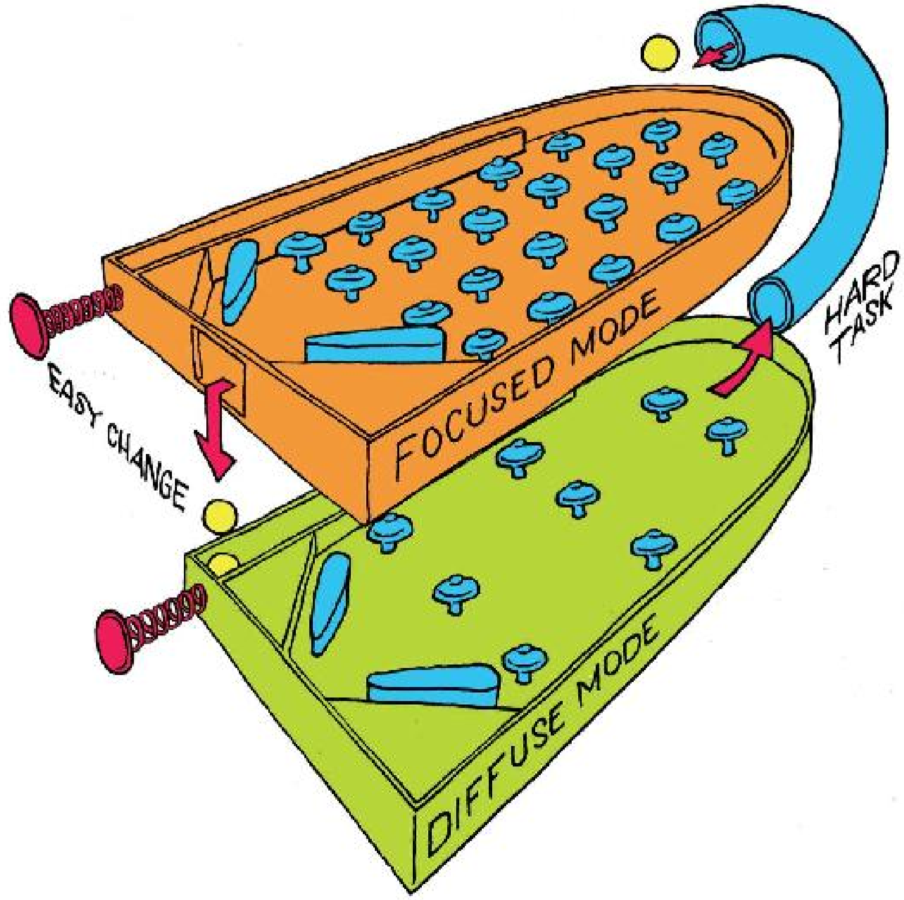
The focused mode—Eyes on the prize!
The diffuse mode—Eyes on the flies![2]



Switching Between Focused and Diffuse Modes

If switching between modes is so important, how do we do it?

Well, if we want to focus on something, it's easy. As soon as we make ourselves turn our attention to it, the focused mode is *on*. Your thought-ball goes swooshing around on that table. Unfortunately, it's difficult to *keep* our attention on something for long periods of time. That's why we can sometimes fall into diffuse mode and begin daydreaming. As you can see in the picture below, if you let go of the flipper, your thought-ball falls down onto your diffuse table, underneath the focused table.



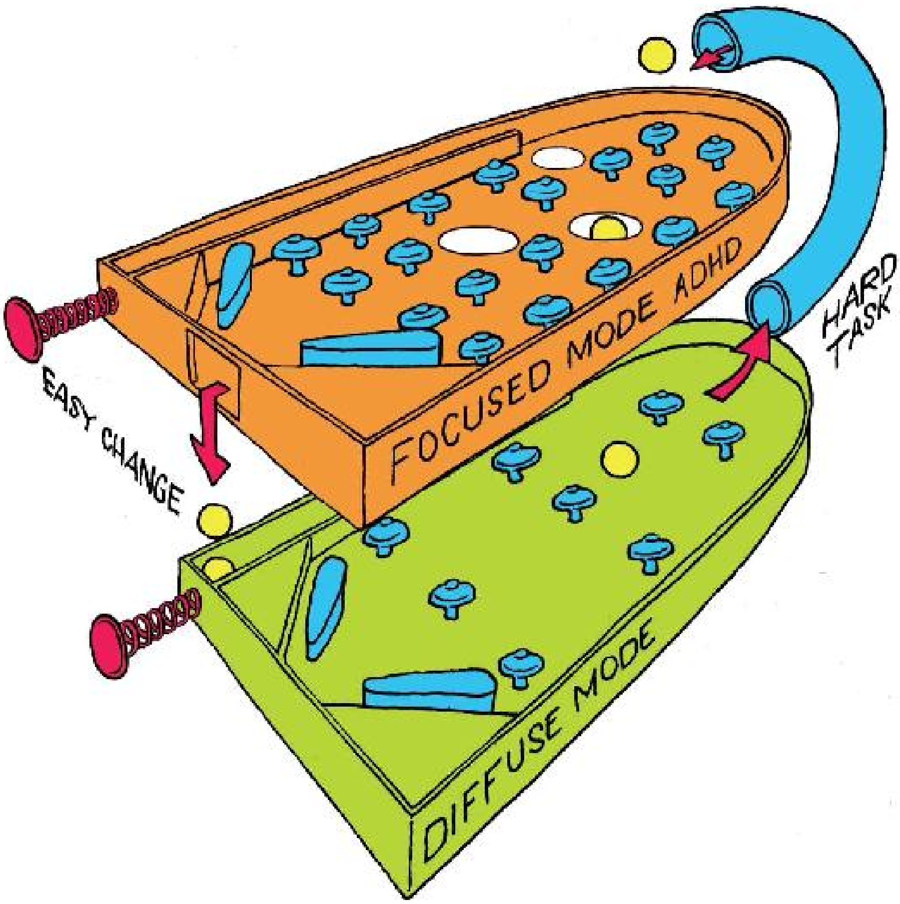
Your mind stays in focused mode as long as you keep using the flippers. But when you let go of the flippers, your mind *goes free! The ball drops down onto the diffuse table.*

Diffuse mode is when we're not focusing on anything in particular. You can enter diffuse mode by just letting go and *not* concentrating on anything. Going for a walk helps. Or looking out a window from a bus. Or taking a shower. Or falling asleep. (Many famous people have had great insights when the events of the day were sloshing around during sleep.[3])

It also seems that focusing on *something else* can take us temporarily into diffuse mode related to what we're *not* focusing on. When we focus on cuddling our dog, we're not focusing on the math problem. When we're focusing on someone else's chess game, we're not focused on our own chess game. This is why, when you're stuck on a math problem, you can instead switch your focus to studying geography for a while. Then you can make a breakthrough when you return to the math. But it seems that the best ways to give your diffuse mode a chance to work out a difficult problem are through activities like sleeping, exercising, or going for a ride in a vehicle.

Kids with ADHD* sometimes like to imagine that their focused pinball table has a few extra "holes" in it. These holes offer a hidden advantage—they boost creativity! If you have ADHD, the "extra holes" also mean you need to work your mental flippers a little more often than other kids to keep your thought-ball on the focused table.

How do you work the flippers more? Participate as much as you can by asking questions, writing on the chalkboard, distributing activities among your partners, and working with them whenever you have an exercise together.



Kids who have problems paying attention like to imagine that their focused mode has a few extra holes in it. This may mean they have to work their mental paddles harder to get the ball back up into focused mode whenever it might fall out—but it also means they can naturally be very creative. Not a bad trade off!

Now You Try! Shifting Modes

Here's an example to help you feel the shift from focused to diffuse mode.

Use all the same coins to make a new triangle that points down. You can move only three coins. (You may want to try this by laying real coins in front of you to see if you can work it out.)

Clue: When you relax your mind and focus on nothing in particular, the solution comes most easily.

Some kids get this exercise instantly, while some professors just give up because they're focusing too hard.

The solution for this challenge is in the notes section at the back of the book.[4]

Getting Stuck

There are two ways you can get stuck when you're trying to solve a math or science problem. Or when you're trying to learn something new, like how to play a chord on the guitar or perform a specific move in soccer. The first way you can get stuck happens when you don't catch the initial explanation. Unfortunately, with this kind of "stuck," going into diffuse mode won't be much use. You haven't "loaded" anything into your focused mode. Your best bet is to go back and look at the examples and explanations in your notes or the book. Or ask the teacher to explain again. Or look on YouTube for an additional explanation. (But don't let yourself get distracted by other videos.)

The second way you can get stuck is when you've studied or focused carefully—you've loaded the explanation into your focused mode. But as you begin to work the problem, play the chord, or make the move, you still find yourself stuck. You grow more and more frustrated. *Why can't you get it?*

It can be easy to get frustrated with your studies.

The reason you get stuck is that you haven't given your brain's diffuse mode a chance to help out! The diffuse mode can't get going until you take your attention *off* what it's focused on. Like Magnus Carlsen, the chess player in the picture a few pages back, sometimes you need to take a break in order to coax your brain's diffuse mode to come to the rescue. Get your mind away from the situation for a while. It opens up your access to the brain's diffuse mode.

Alternatively, focus on something different. For example, if you're working on algebra, you could switch to studying geography. But keep in mind that your brain also needs a little rest sometimes.

If there's something you tend to get stuck at, start with this subject when you are studying. That way you can go back and forth to your other class work over the course of the afternoon and evening when you might find yourself getting stuck. You don't want to leave your hardest subject to the end when you are tired and have no time for diffuse learning.

When you're in diffuse mode, your brain is working on the problem quietly in the background, although you're often not aware of it. The thought-ball in your mind is whizzing around your diffuse mode table, and it can bump into the ideas you need to solve the problem.

When you take a break, how long should it be? This depends on you and how much material you need to cover that day. Five or ten minutes is a good break time. Try not to make your breaks too long. You want to finish so you'll have part of the evening to relax!

Important Learning Tip: Don't Jump to Conclusions about Whether or Not New Learning Strategies Work

Don't try switching just once between focused and diffuse modes while you're studying and then decide that it doesn't work for you. Sometimes you have to go back and forth several times between focused and diffuse to figure something out. You need to focus hard enough on trying to understand the material before you take a break.

How long should you focus? As a rough guideline, if you find yourself stuck after at least ten to fifteen minutes of trying (maybe three to five minutes if you are younger), it may be time for a break. When you do take a break, you need to make sure it's long enough for you to get your mind completely off the material.* It's worth sticking it out and experimenting with the process.

Going back and forth between focused and diffuse modes will help you to master virtually anything, whether it's geometry, algebra, psychology, basketball, guitar, chemistry, or any other subject or hobby you're interested in learning.

Use These Diffuse Mode Tools as Rewards After Focused Mode Work

General Diffuse Mode Activators

- Play a sport like soccer or basketball
- Jog, walk, or swim
- Dance
- Enjoy being a passenger in a car or bus
- Ride a bike
- Draw or paint
- Take a bath or shower
- Listen to music, especially without words
- Play songs you know well on a musical instrument
- Meditate or pray
- Sleep (the ultimate diffuse mode!)

The following diffuse mode activators are best used briefly as rewards. These activities may pull you into a more focused mode than the preceding activities. It can sometimes be a good idea to set a timer, or they can eat up too much time.

- Play video games
- Talk to friends
- Help someone with a simple task
- Read a book
- Message friends
- Go see a movie (if you have the time!)
- Watch TV

SUMMING IT UP

Focused and diffuse modes. Our brains operate in two modes: focused and diffuse. You can think of them as pinball tables that have tightly packed bumpers and spread-out bumpers. We need to alternate between these two modes to learn well.

Shifting modes. You shift into focused mode by focusing. Grab those flippers on the pinball machine! But you have to let go and wait for the ball to drop on its own to get into the diffuse mode. The bed, the bath, the bus, and simply going for a walk are great ways to fall into the diffuse mode.

To be a successful problem solver, focus first. We get stuck in problem solving when we don't first prepare our brain by focusing on the basics. Don't just dive into problem solving without studying the explanations first. You need to lay some basic trails on the focused pinball table.

Take breaks to get new problem-solving perspectives. We can also get stuck on a difficult problem even when we've prepared properly. In that case, be a little like the chess-playing Magnus. Wander off for a while and see what else is going on. Take a break. But come back to the game, or you'll lose for sure!

You can choose to go into focused mode. But the diffuse mode is trickier to fall into—the bed, the bath, and the bus, or simply walking, are great ways to summon this more relaxed state of mind.

CHECK YOUR UNDERSTANDING

See how well the key ideas of this chapter have crept into your brain by writing down your answers to the following questions. When you're done, you can compare your answers with the ones at the back of the book.

You may think you can skip these questions, but if you do, you will begin to lose the benefits of this book.

1. What does it mean to be in *focused* mode?
2. What is *diffuse* mode? And what are your favorite diffuse activities?
3. How does a pinball machine (or two) help you understand how your brain works?
4. What is another metaphor for *focused* and *diffuse* modes?
5. What are the two different ways you can get stuck when you are solving a math and science problem?
6. What's the one study habit that you would change as a result of reading this chapter?

Did you do a picture walk yet of the next chapter? Did you try to answer a few end-of-chapter questions? Do you have a notebook out? (Check this off when you're done!) ☐

CHAPTER 3

I'LL DO IT LATER, HONEST!

Using a Tomato to Beat Procrastination

Back in the 1800s, murderers used to love a chemical called arsenic. (It's pronounced "ARE-suh-nick," and sounds like "parsnip.") Arsenic poisoned and killed victims in a day. Painfully.

In 1875 two men ate arsenic in front of an audience. People expected them to die. But to everyone's surprise, they returned the next day, alive and well. How was that possible? How can something so harmful appear to do no damage?

It was a mystery.

We'll tell you later how the story of the arsenic eaters ended, but . . . spoiler alert: It didn't end well for them.

Arsenic is bad for us, but tomatoes are good, right? They are full of healthy nutrients. I'm going to show you how even a plastic tomato can be good for you. It can help you learn better. Sound crazy? All will soon become clear. But don't eat any plastic tomatoes. That's not the trick . . .

The Problem with Putting Things Off

I want to tell you about procrastination.* **Procrastination means putting things off until later.** It is a problem for many students (and adults!) and gets in the way of good learning. Procrastination can be a natural thing to do. Why would you do something you don't feel like doing? Especially if you know it's going to be hard? Why study on Monday when the test is not until Friday? Won't you forget it by then anyway?

Here's the problem. If you procrastinate, you often run out of time. As you will learn later, time and practice work together to help you cement new ideas into your brain. If you run out of time, you not only can't build learning structures, you also spend energy worrying about it. That's a lose-lose situation. Procrastination is the enemy of high-quality learning. But many students still do it. I want to show you how to beat it.

Here's the good news. Your inner zombies are going to help you learn. Now don't freak out. I don't mean you have real zombies inside your skull. That would be gross. But it's nice to imagine an army of tiny zombies up there, working hard for you. You want to make friends with them.

So, we need a pinball machine, a headful of friendly zombies, and a plastic tomato? Who knew? Stay with me . . . I'm a professor!

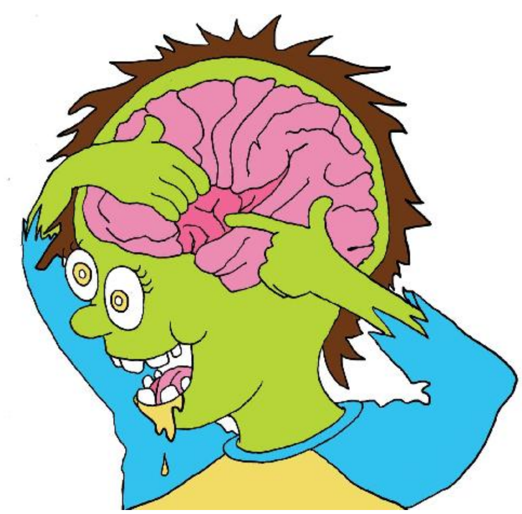
Distraction and Procrastination

Procrastination is a major problem. We have so many distractions. I always think, “Before I start my homework, I’ll play a video game.” Before I realize it, I have wasted an hour. I need to find a way to focus on my homework. I should not be waiting until the last minute to do everything.

—A math student

Procrastination and Pain

Do you groan when your mom or dad tells you to clean, or practice an instrument, or start your homework? This is because when you think about opening that book, or cleaning up, it actually hurts—researchers can see an area of the brain that experiences pain, the insular cortex, begin to light up. To your brain, thinking about cleaning your room feels like the start of a stomachache. But here's what's interesting. Once you get started on the task you didn't want to do, the pain goes away after about twenty minutes. The insular cortex calms down when you start the task you were avoiding. It's happy that you're finally getting on with the job.



When you even just think about something you don't like, it activates a pain center of the brain called the insular cortex. This can lead to procrastination. (The helpful zombie here is showing you the location of the insular cortex.)

So this is my number one top tip to become a good learner. Just get going. Don't put work off until later.

Easy for the professor to say, you're thinking. How can I change my habits? I'm so used to them.

The answer is . . . a tomato!

The Pomodoro Technique

Has she gone crazy? you ask. How can a tomato make me a better learner?

In the 1980s Francesco Cirillo came up with a way to help procrastinators. It's called the Pomodoro Technique.

Pomodoro is Italian for "tomato." Cirillo developed a tomato-shaped timer, like the one here. Cirillo's technique is simple, and it works. (Terry and I know. It is one of the most popular techniques in our course Learning How to Learn.)

A Pomodoro timer

First, you need a timer. The tomato-shaped timer is great, but any timer will do. I have a digital timer on my computer. Many people use Pomodoro apps on their smartphones or iPads.

The technique works like this:

1. **Shut off all distractions**—your phone, the TV, your music, your brother. Anything that gets in the way of your ability to focus. Find

a quiet place to work where you won't be interrupted. If you can afford them, consider noise-canceling earphones or cheaper but just-as-effective earmuffs or earplugs.

2. Set the timer for **25 minutes**.*

3. Get going, and **focus** on the task as well as you can. Twenty-five minutes is not long. You can do it!

4. Now for the best part. After 25 minutes, **reward** yourself. Watch a dance video or listen to your favorite song. (Maybe dance to it yourself!) Cuddle with your dog. Or chat with friends for five or ten minutes or so. The reward is the most important part of the whole Pomodoro process. When you're looking forward to a reward, your brain helps you focus better.

When you're done with your Pomodoro, reward yourself!

We're going to call this whole process, including the reward, "doing a Pomodoro."

When you "do a Pomodoro" forget about *finishing* the task. Don't say, "I'm going to finish all my homework during this Pomodoro." You *might* finish whatever you're working on. But don't worry about it if you don't. Just work as hard as you can for 25 minutes. When the timer goes off, take a break. Dip into your diffuse mode with that reward.

You may need to do another Pomodoro later, but that's okay. You're doing the right thing just by working hard on the task. Don't worry about how much you do. You will finish. But leave yourself plenty of time. Don't wait until the last minute.

When I do a Pomodoro, my thoughts sometimes wander off. That's perfectly normal. As soon as I catch my thoughts wandering, I just bring them back to the task. It's only 25 minutes, after all. Anyone can do 25 minutes of studying. If I find my thoughts wandering to other tasks I want to do, or websites I want to check, I make a note on a piece of paper so I won't forget, and then I continue with the Pomodoro.

I'll admit that if I *want* to keep working after the time is up, I go ahead. Getting into the flow, where I'm really into doing the task, is a good thing. But when I stop, I always reward myself. It's diffuse mode time! If I've been writing (like this book), I listen to a favorite song. Or I get up and make a cup of tea and look out the window. I don't write during my break. That way, the "writing" part of my brain gets a rest.

It's a good idea to do something during your break that's very different from what you have been focusing on. You want to give a rest to the area of your brain that's been doing the focusing. If you've been sitting while you study, breaks where you move your body around are often the best.

Some people like Pomodoro timers that make a ticking sound. This reminds them that time is passing and they are getting closer to their break. The ticking keeps them focused.

How many Pomodoros should you do in a day? That depends on you. If you're pretty self-motivated and just need an occasional poke to get going, try doing just one or two Pomodoros a day, when you need them. Some people keep careful count of how many Pomodoros they do in a day—they often use Pomodoro apps that collect the day's Pomodoros, kind of like badges. Look up Pomodoro apps and find one that you like—one of the most popular ones we know of is called "Forest."

By the way, don't switch between tasks when you're doing your Pomodoro. Pick a task and work at it until the bell rings. (Of course, if you *finish* a task during a Pomodoro, you can start another.) Some students think they can do several tasks at once, or switch back and forth between several tasks at once. This is called multitasking. But the idea of multitasking is a mistake. Your focus can only be on one thing at a time. When you switch your attention, you waste mental energy, and you will perform worse. It's like a pinball machine where two balls have been released instead of one, and you have to crazily try to manage both the balls. You inevitably fail and both balls drop.

Learning Tip: Set a Timer for Your Breaks—and Learn to Put Off Your Procrastination!

Just as the Pomodoro timer can be useful for your studies, it can also be useful for relaxing. Set your timer for five, ten, or however many minutes make sense for a break. Remember—taking a break is important so your diffuse mode can help your learning!

For some people, it takes practice to get used to coming back to a task after a break ends. A break timer that has a very distinct and loud sound can be useful here.

Sometimes people find it hard to stop procrastinating. If that's the case, a good mental trick is to tell yourself that you're going to procrastinate *ten minutes later*. Meanwhile, during those ten minutes, look at (or make) a list of what you plan to do. This will allow your diffuse mode to start thinking in the background about your tasks and how you're going to get them accomplished.

Good Zombies and Bad Zombies

This takes me back to zombies. Sometimes they have a bad reputation. People think of them as monsters—scary-looking creatures who are under the control of something or someone else.

But zombies (at least in our book!) are just your habits. There are good, neutral, and bad zombie habits. (Okay, maybe the bad zombies really aren't that bad—they're just not helpful sometimes.)

What do all zombies have in common? They work automatically toward their goal (which generally involves eating brains). Nothing distracts them. They never give up. It's like they're on autopilot.

Your habits are like zombies—you can have bad ones or good ones.

We all have a zombie mode—fortunately, it usually doesn't involve eating weird substances, like with real zombies. We do things automatically because we've done them so many times before. What are your zombie mode habits? Throwing your shoes down as you come in from school?

Falling into a favorite chair in front of the TV? Or reaching for your phone as soon as it vibrates? No thinking. No discussion. That's you in zombie mode.

Imagine being as focused as a helpful zombie on your studies during the time you're supposed to be studying. Practicing the Pomodoro Technique will help you get there. But you need to defeat your bad zombie habits on the way.

Studying and texting in the same time frame is a bad habit. It's your bad "study while texting" zombie. To defeat it, you can instead train a helpful zombie—get used to turning your phone off, silencing it, or leaving it in another room. The new good zombie can allow you to overcome the bad one!

If your brother interrupts you, train your helpful inner zombie to tell your brother you're "doing a Pomodoro." Ask your brother to stay away until you've finished. If you know you get hungry, have a snack *before* you do a Pomodoro. Instead of mindlessly jumping into a new chapter of your textbook, first do a picture walk, and then take notes on the paper that your good zombie mode has thoughtfully placed beside you. Replace your bad zombie habits with ones you know will make things better for you.

Back to the Arsenic Eaters

Remember the arsenic eaters? How did they eat arsenic and not die on the spot? And what does eating a deadly poison have to do with something as seemingly harmless as putting things off—procrastination?

The arsenic eaters ate a little bit of poison each day. They trained their bodies to expect it. They were building up an immunity. They thought they were getting away with it because they didn't feel ill.

They didn't realize it, but they were gradually poisoning themselves.

A little bit of arsenic won't kill you right away. But it's very unhealthy. Over time it does serious damage—cancer and other damage to your internal organs. Don't eat arsenic!

How is this like procrastination?

It doesn't seem like it hurts if you put off your studies a little longer. Or spend another "few minutes" on social media. But if you get used to procrastinating, it will make learning harder, because you will have less time when you do buckle down to learn. You'll get stressed, miss deadlines, and not learn things properly. You can get really behind. All this will make you a less effective student.

Remember, you can build an army of helpful zombies up there, working hard for you if you make short periods of focused concentration into a habit. So learn to love that plastic tomato! Or the Pomodoro app on your phone.

Now You Try! Preplanning to Avoid Distraction

Write down the things that distract you from the task at hand. For each one, come up with a new habit to work on. (If you're reading this on an electronic device, make your own table on paper.) Here's an example to get you started. If you are younger, you may want to sit down with an adult for ten minutes or so to get you started.

DISTRACTION: Bad Zombie	SOLUTION: Friendly Zombie
My phone vibrates–I stop working.	Leave phone on the kitchen table when doing a Pomodoro.

Now You Try! Boost Your Reading Power with Active Recall

We want to give you a sneak preview now of an important learning technique that will help you in the chapters ahead. This technique is called *active recall.* Active recall means bringing an idea back to mind. *Actively recalling* key ideas you are learning has been shown to be a great way to understand them.[1]

You can probably guess that we've been teaching you how to avoid procrastination so you have more time for important techniques like active recall.

Here's how you do it. Before you begin to read a chapter in a book, first do a picture walk through it. (We talked about this at the end of the first chapter.)

Then begin reading. Don't rush. Go back over a paragraph if it doesn't make sense to you or if your attention wanders. (Wandering attention is perfectly normal. It doesn't mean you're not smart enough.) Jot a few words in the margin or on another sheet of paper about an idea you think is important. If you need to, underline a key word or two, but not too many.

This is the critical part. Look away from the page and see what you can recall. What are the key ideas on the page? Play them back in your mind. Or say them out loud to yourself. Do not simply reread the page over and over again. And don't underline or highlight big amounts of text.

Pulling the key idea from your own mind, instead of just reading or rereading it on the page, is the critical idea behind active recall. You don't need to use recall with every page of the book. But if you try it on a few key pages, you'll be surprised at how this can help.

Research has shown that if you use active recall in your studies, you will do much better later when you are taking tests.

Using recall in your learning means you can perform well even when you're under stress.[2] And it doesn't just put information into your memory—it also builds your understanding.[3]

The Three Key Steps to Powerful Reading

1. Picture walk
2. Read with care
3. Use active recall

You can also use active recall as a great general learning tool. For example, close this book and see how many key ideas you've read so far that you can remember. Once you've done your best, open the book back up and see how it compares!

Recall the information at different times and in different places. You can use active recall while waiting for a friend, sitting on a bus, or before going to sleep. There are two important reasons to use recall in this way. First, you don't have your notes or the book in front of you, so you are truly recalling the information, rather than sneaking a peek. Second, you don't have your usual study environment around you. As you'll see later, learning in different places can glue the information more strongly in your mind.

When I was in middle school, I used to walk to my grandma's house for lunch. As I was walking, I would try to recall key ideas that I'd just learned in the class, as if rewatching an

interesting film. This technique helped me tremendously to excel in my studies.

—Zhaojing "Eileen" Li, graduate of Tsinghua University—China's top university

SUMMING IT UP

- We all develop habits. They're our inner zombies. Things we do without even thinking about them.
- **Our zombie habits can be helpful or not.** Some are great time savers. But often people develop the habit of putting off their work—procrastination. This is really bad for effective learning. It doesn't leave you enough time to focus or to soak in the lessons you've learned.
- Luckily you can change your habits and make them stick. **The Pomodoro Technique is a great way of helping you to do focused work.** Make a habit of it. Shut off distractions and set a timer to work for 25 minutes. Easy. Then take a break and reward yourself. Do something "diffuse."
- **When you put something off, it's hurting your brain.** Just getting going stops the suffering.
- ***Active recall* is a powerful technique for learning.** Pull key ideas *from your own mind* to review them. Don't just look at a page or your notes and fool yourself into thinking that the information is in your head.

CHECK YOUR UNDERSTANDING

To make sure you've got the hang of this chapter, answer the following questions. Say the answers out loud to yourself or write them down or try to *teach* someone else the answers by explaining what you have learned.

When you're done, you can compare your answers with the ones at the back of the book.

1. What is procrastination?
2. Why is procrastination bad for your learning?
3. What happens in your brain when you think about something you don't like or don't want to do?
4. How would you explain the Pomodoro Technique to someone who had never heard of it?
5. What is the most important part of the whole Pomodoro process?
6. What should you do during your break between Pomodoros?
7. Should you plan to finish a task during a Pomodoro? Why or why not?
8. What can be good about going into zombie mode?
9. What does zombie mode have to do with procrastination?
10. What was the point of the arsenic eaters story? How does it link to procrastination?
11. Explain the idea of *active recall.*

Picture walk done, a few end-of-chapter questions tackled, and notebook ready for the next chapter? ☐

CHAPTER 4

BRAIN-LINKS AND FUN WITH SPACE ALIENS

Santiago was eleven years old and in trouble. Big trouble. This time, he landed in jail.

He'd had it coming. Santiago argued endlessly with his father and fought with his teachers. He was kicked out of school, time after time. But this time, he had blown a hole in a neighbor's gate with a homemade cannon!

He hated school. He didn't have a good memory, which made it hard for him to learn in exactly the way teachers wanted him to learn.* He especially hated math and didn't see the point. He liked to draw, but his father thought drawing was useless.

Santiago was going nowhere fast. But guess what? Santiago eventually won a Nobel Prize—that's like an Olympic gold medal for science! He became the father of modern neuroscience. "Bad boy" Santiago Ramón y Cajal* became one of the greatest scientists of all time.[1] He used art skills *and* math skills.

We're going to tell you how it happened. But first, let's learn a little about the brain. This will allow you to understand one of Santiago's breakthrough discoveries. It will also help you understand how we learn!

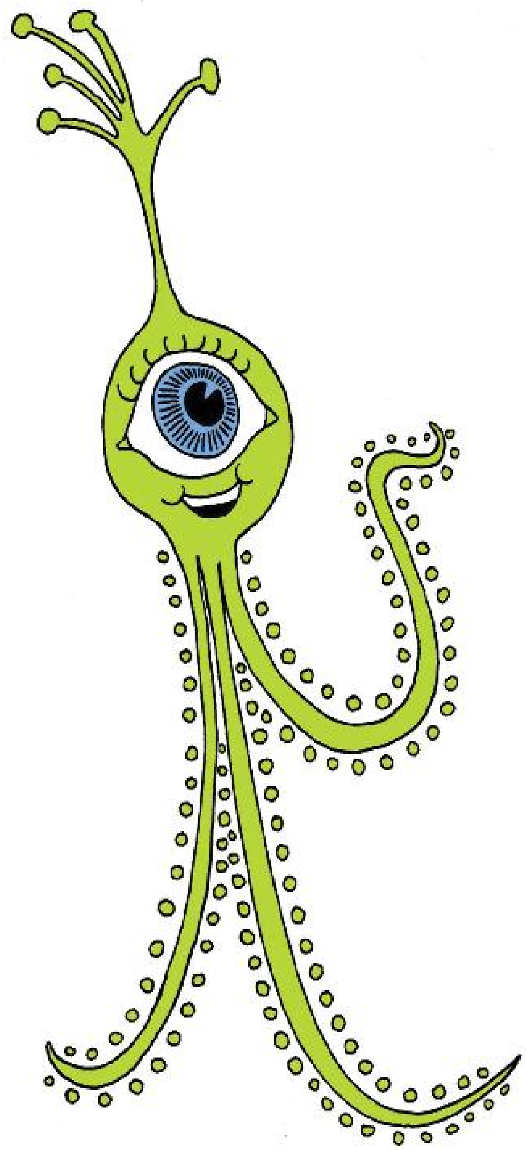
Friendly Space Aliens: How Neurons "Talk"

Let's start with a few simple ideas about the brain.

Your brain has a lot of neurons in it. Billions, roughly the same number as the number of stars in the Milky Way galaxy. Neurons are the building blocks of your brain. They're small. Really small. Ten neurons are only as wide as a human hair! But they can be long—longer than your arm.

To understand neurons, you can think of tiny aliens from outer space.

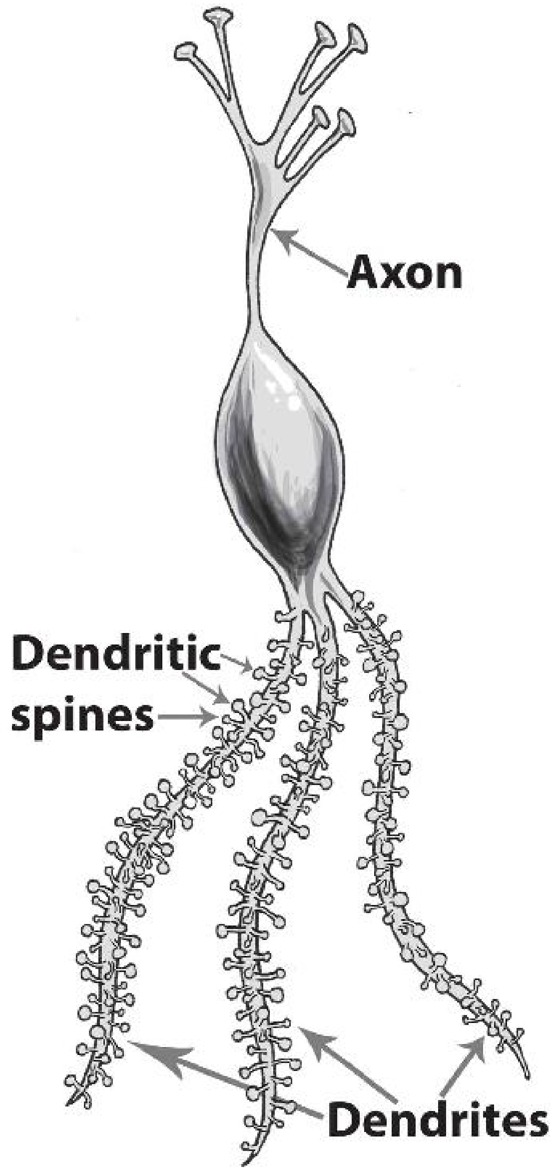
Yes, aliens. Can you see the eye of the neuron-alien below? (Technically, the eye is called the *nucleus*—there is a nucleus in every cell in our body.) The neuron-alien's single arm stretches above, almost like a hat. The neuron-alien's three legs are underneath.



A neuron-alien—our metaphor for a real neuron.

Neuron-aliens are bizarre creatures. They have only an eye, one arm, and three legs. (In real life, neurons can have more than three "legs." Lots more! They come in many shapes and sizes, with more variety than all the other types of cells in your body.)

Below is a drawing that is much closer to the look of a real neuron. Down below are the neuron's "legs." They're called *dendrites*. Up above is the neuron's "arm." It is called an *axon*.*

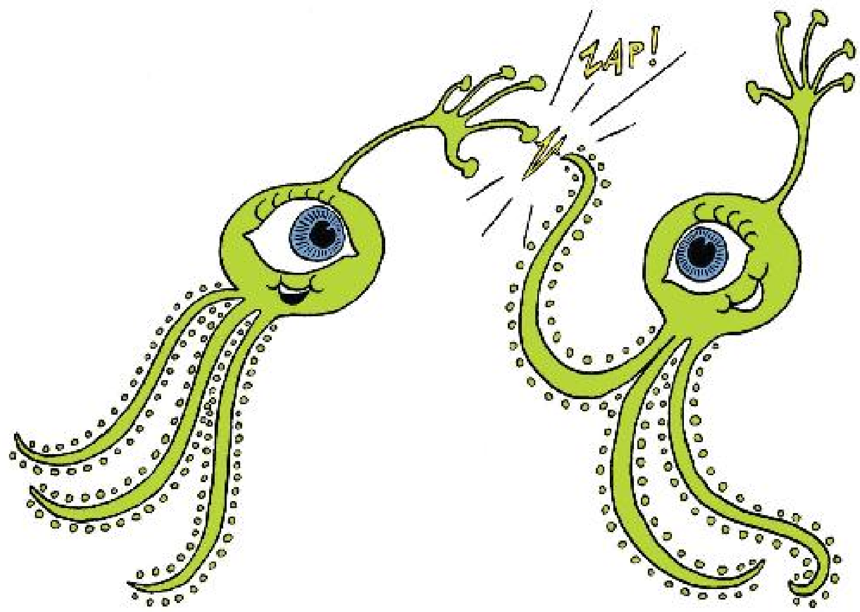


This is a neuron having its usual "bad hair" sort of day.

Look at those knobby spines on the dendrite "legs" of the neuron. Those are called *dendritic spines*. They are like toes scattered all over the space alien's legs. (Remember. This is an *alien*. It doesn't look like we do!)

Dendritic spines may be tiny, but they are important. You'll see them again in some unexpected places in this book.

Here's a key point: Neurons send signals to other neurons.

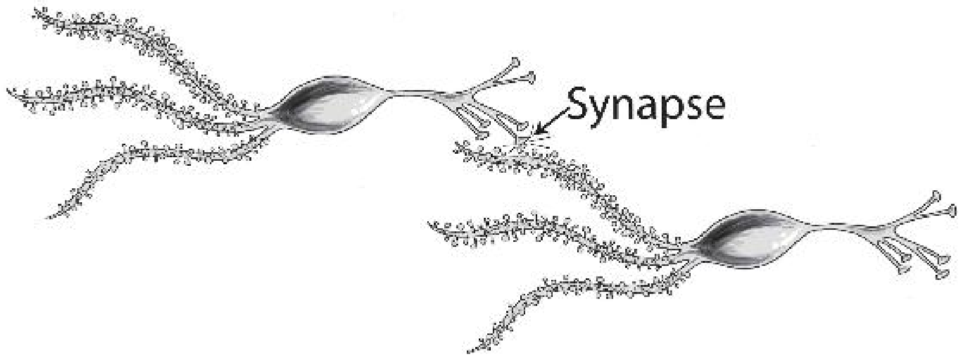


What's new, Ron?

It's easiest to understand this by returning for a moment to our space aliens. When one neuron-alien wants to "talk" to the next alien, it reaches its arm out and gives the tiniest of shocks on the toe of the next alien. (These particular aliens show friendship by giving tiny shocks to one another. Weird, I know.)

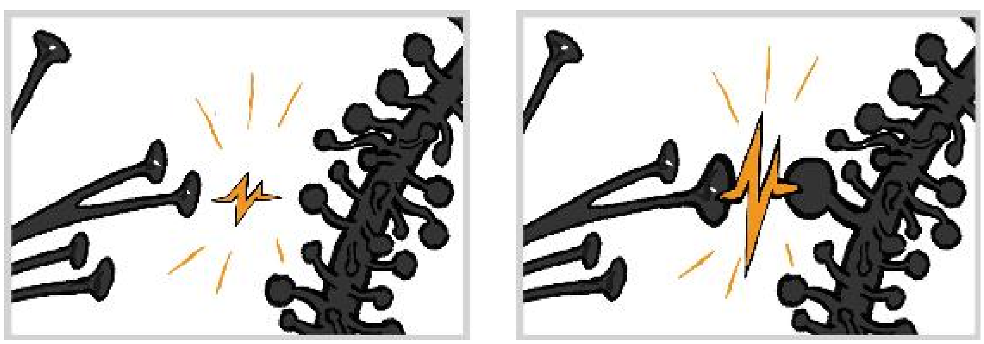
It's similar for real neurons. A neuron ripples a signal along its axon to cause a shock in a dendritic spine of the next neuron.[2] It's like the tiny shock you feel with static electricity on a dry day. One neuron sends a shock across a tiny, narrow gap to another neuron. This gap is called a *synapse*. (It's pronounced "SIN-naps" in the United States and "SIGH-naps" in England.)

There. You've just understood the process of how a neuron passes along a signal! Okay, maybe it's more complicated than that—there's some chemistry involved. But you now understand the basics.



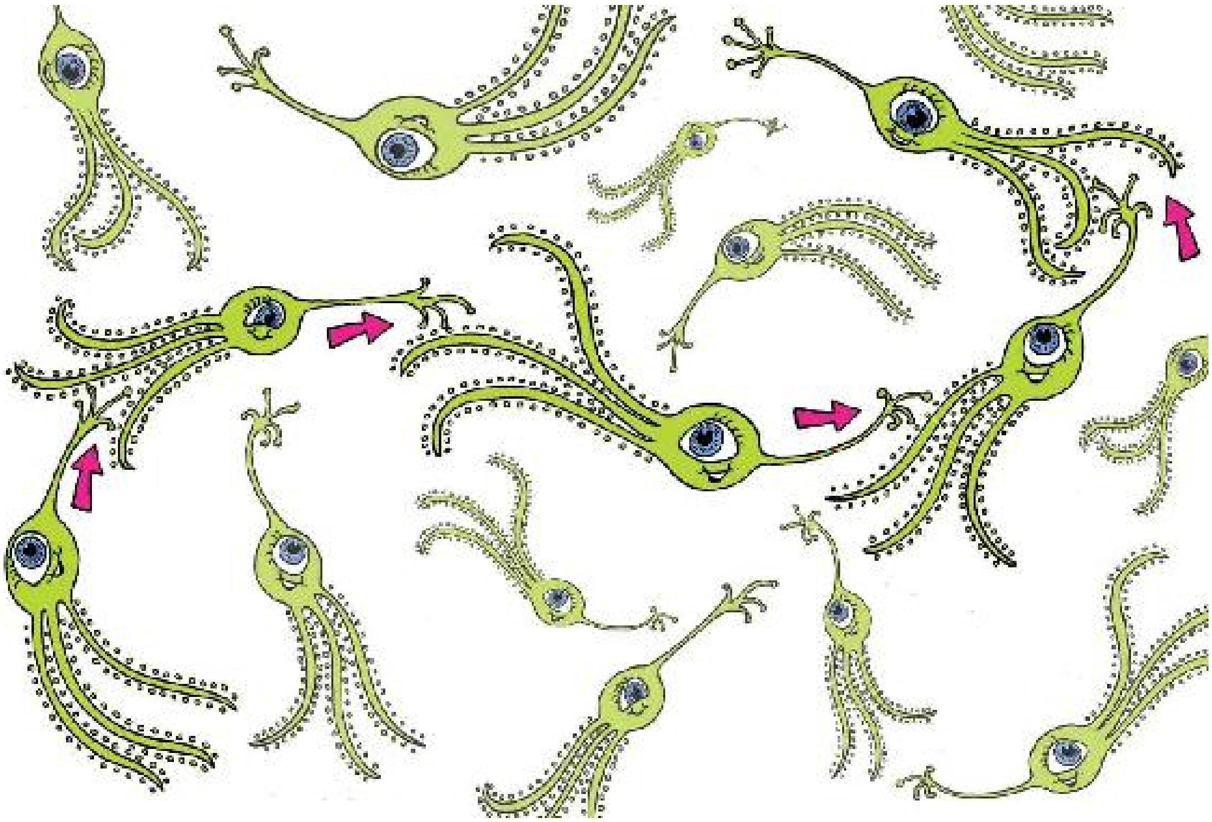
Two neurons connect together across a synapse.

You can also see a close-up view of a synapse. The “spark” from the synapse creates an electrical signal that can flow through the neuron. If the signal reaches the end of the axon, it can cause a spark in the next neuron. And the next. And the next.* *These flowing signals are your thoughts.* They’re like the trails on your mental pinball table.



On the left is a close-up of a small synapse. See the little “spark”? On the right is a bigger synapse that has grown because of practice. See how much bigger the spark is?

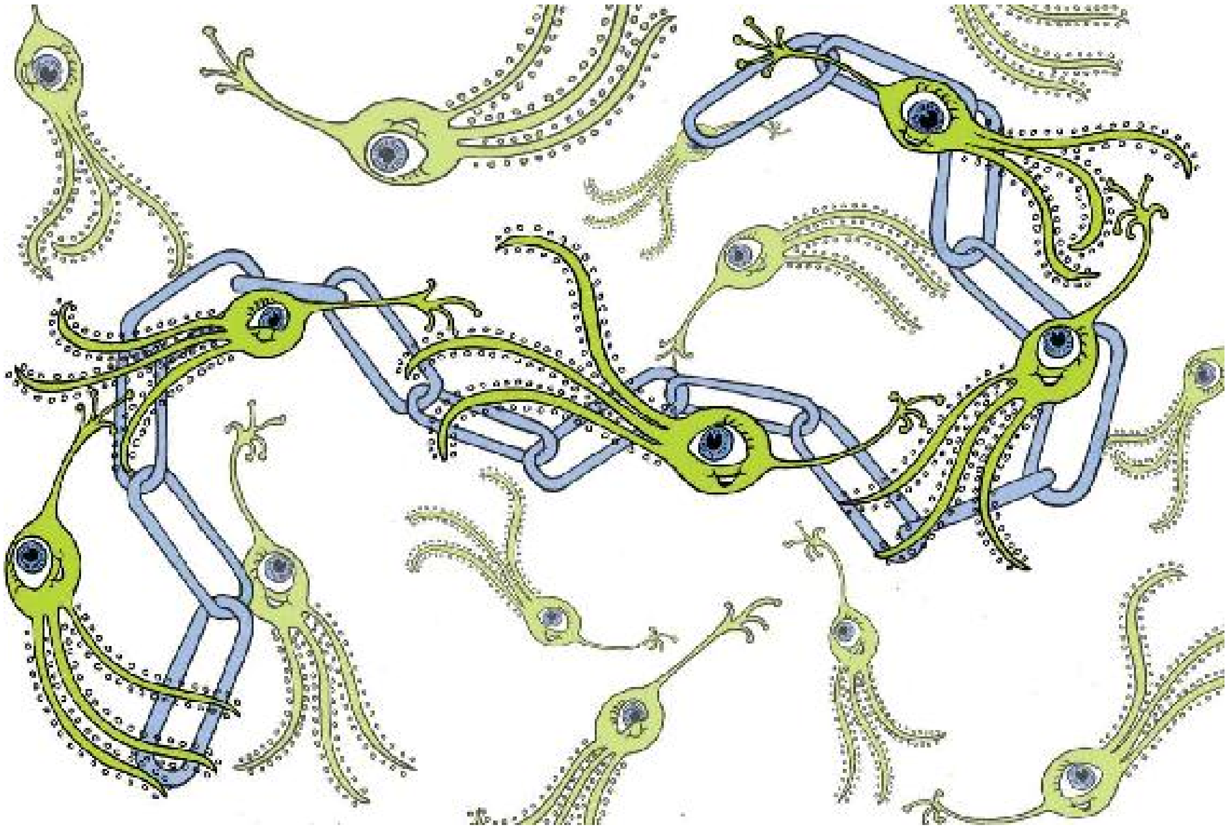
The arrows in the picture below show how a signal could flow through the synapses and the neurons.



Signals flow across neurons—these create your thoughts!

Let’s return again to our friends the neuron-aliens. The more often a neuron-alien shocks the next neuron-alien so that it passes the message on to its friends, the stronger the connection between them becomes. The neuron-aliens are like friends who become better friends because they talk a lot.

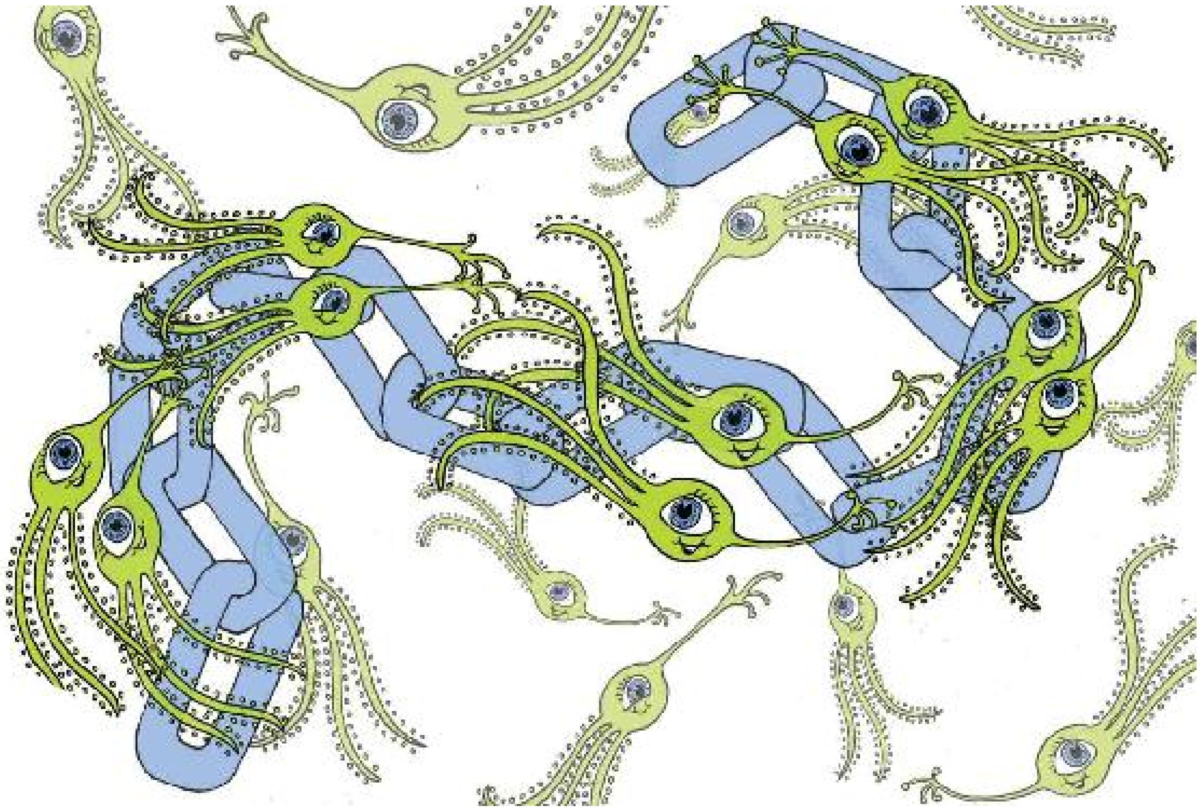
It’s like that for real neurons, too. Researchers often use the phrase “Neurons that fire together, wire together.”[3] You can think of the “wiring together” as creating a *set of brain-links*. Learning something new means creating new or stronger links in your brain. A new set of brain-links![4]



A weak set of links forms when you begin to learn something.

When you first learn something new, the brain-links are weak. There may be only a few neurons linked together. Each neuron may have only a small dendritic spine and a small synapse. The spark between the neurons isn't very big.

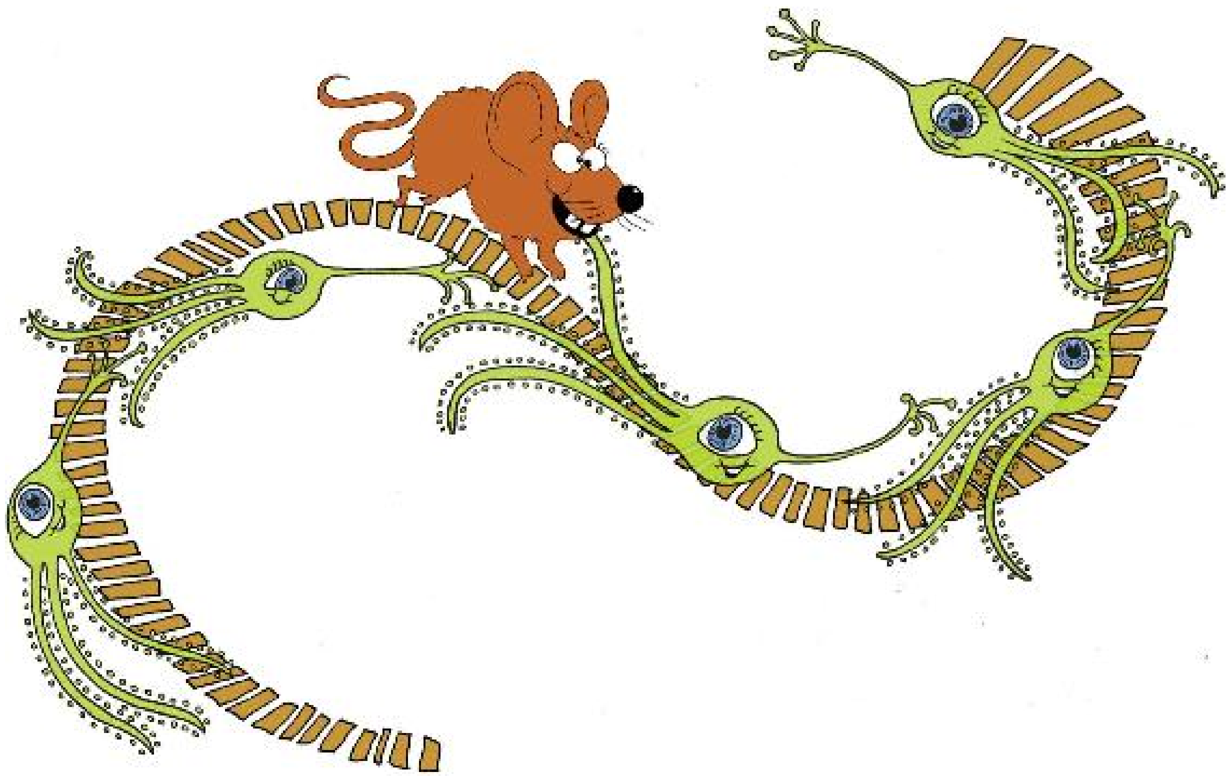
As you practice a new idea, more neurons join in.[5] And the synaptic links between the neurons get stronger. This means the sparks get bigger. More neurons, stronger synapses—the brain-links get stronger, too![6] Longer brain-links can store more complex ideas. The opposite happens when neurons don't fire together—their connections weaken, just like two friends who don't talk anymore.

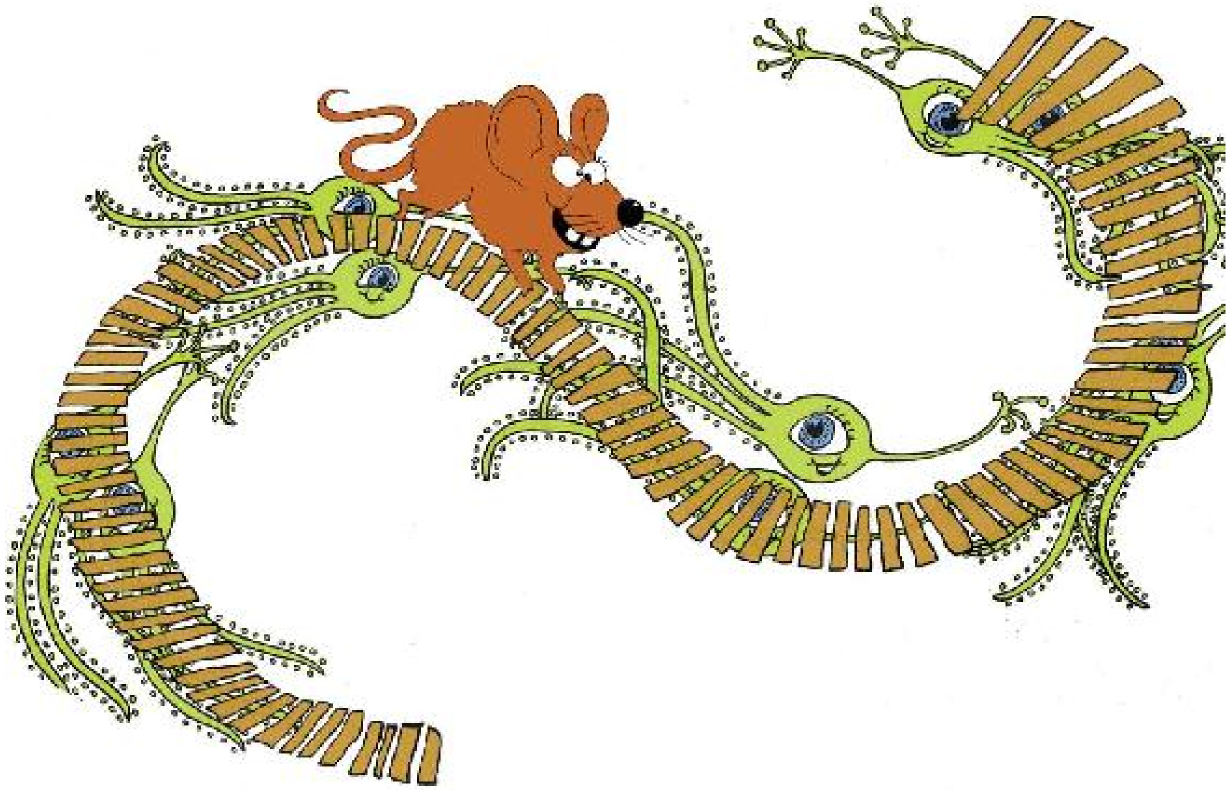


The more you practice, the stronger your set of brain-links gets.[7]

Some people like to think of a set of brain-links as if they were paths that a mouse runs along in a forest (the mouse is like the bouncing "thought-ball" in the pinball machine metaphor). The more times the mouse runs along the pathway, the clearer the path becomes. The wider the path is, the easier it is to see and follow it.

So then, what's the mouse metaphor for the diffuse mode? Simple. In the diffuse mode, the mouse—the thought—doesn't run along the path. Instead, the thought-mouse jumps onto a tiny drone and flies to its new location!





Neural paths get wider and easier to travel on the more your mental "mouse" runs along the path.

Don't worry that you might accidentally use up all your neurons while you're making bigger and wider brain-links. You've got *billions* of neurons —and your brain is growing new neurons all the time. More than that, you can make billions and billions of connections *between* neurons!

The fact that trails in your brain can change and grow is called *neuroplasticity*. (It's pronounced "new-row-plas-TI-sity.") This fancy word just means that your neurons are like clay you can mold. That is, your neurons can change. This is why *you* can change!

Now You Try! Make Your Own Neurons

You can make your own neurons and brain-links. The simplest approach to making a model set of brain-links is to take a strip of construction paper and glue the ends together. Then, take a new strip and thread it through the first one (now a closed circle). Then glue the ends of the second strip together. This can be repeated until your number of "brain-links" reaches its desired length.

More advanced crafters can use pipe cleaners and beads of different sizes—making sure that the pipe cleaners can fit through the beads. Use the pipe cleaners to form the axon, the boutons (which are the "fingers" at the end of the axon), the dendrites, and the dendritic spines. The small balls on the ends of the dendritic spines can be represented by the small beads. The neuron's "eye" (the nucleus) can be a larger bead.

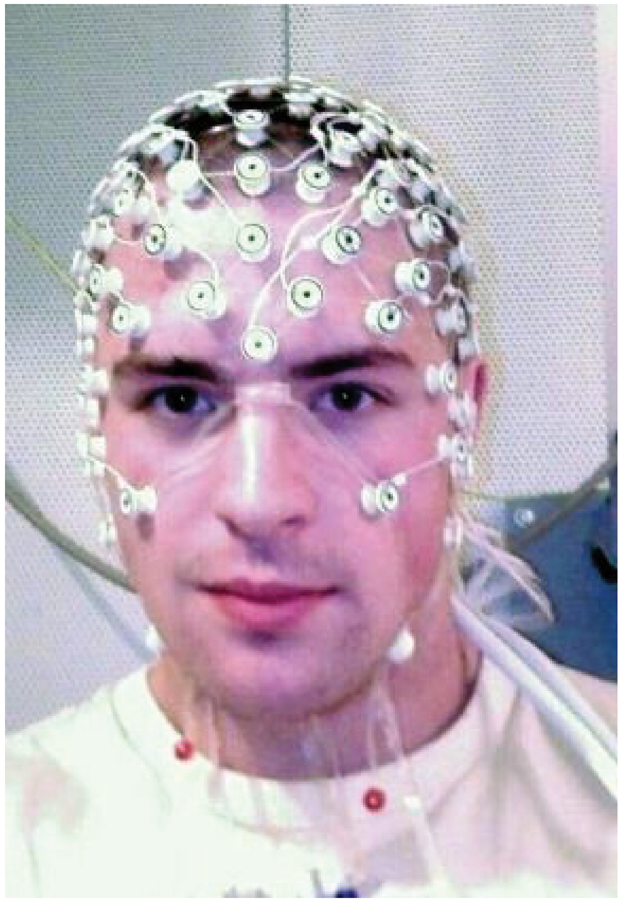
Making your own neurons is a great way to remember all the different parts. By lining your neurons up, axon to dendrite, you can better understand how the neurons "talk" to one another.

A Neuron Mystery

Back when Santiago Ramón y Cajal was around, in the late 1800s, scientists didn't know that the brain was made of individual neurons. Scientists thought that maybe neurons joined to one another to form a network. This network was spread throughout the brain, like a spiderweb.* Scientists believed the brain was a single, spiderweb-like network of neurons because electrical signals flowed so easily between different parts of the brain. How could signals flow so easily if they had to jump from one neuron to another neuron?

The problem was that it was hard to see what was going on. Microscopes weren't good enough to see whether there were any gaps between neurons. The spiderweb theory seemed reasonable at the time. But Santiago thought that there were special gaps between neurons. He believed the gaps were just too small to see. Santiago proposed that signals jumped across the gap a little like an electrical spark. (Similar to how our neuron-aliens send signals by sparking one another!) Santiago was right, of course. Now we can see the synaptic gap with new tools that are better than old-fashioned microscopes.*

Today, neuroscientists can listen to neurons chitchatting in the brain. The electrical waves are easy to see using cool technology like the EEG.* It's like watching ocean waves swooshing along.



Above is a person with EEG sensors on his head. Below are some of the EEG waves his brain is making.

We Love Metaphors!

Can you tell that we like to use *metaphors*? A metaphor is a *comparison* between two things.* One thing is something you are familiar with, like an ocean wave. The other thing is something you may not be familiar with, like an electrical wave. Metaphors allow you to connect what you already know to the new concept you're learning. This helps you learn faster. (Obviously, an electric wave is not the same as an ocean wave, a neuron is not a space alien, and a dendritic spine is not a toe. They just share some similarities.)

Coming up with a creative metaphor is one of the best ways to learn a new concept or share an important idea. That's why some metaphors have meaning in every language, like the Swahili proverb "Wisdom is wealth." Great writers are known for their metaphors. Have you ever heard Shakespeare's line "All the world's a stage"? You are the actor.

When you think of a metaphor, a trail in your brain is activated. (Yes, this trail is the set of brain-links you saw before.) The trail allows you to more easily do complex thinking about the "real" concept. Just by thinking of a metaphor, you've started understanding the tougher concept! Metaphors help you to *get it* faster. (All this relates to something called the "neural reuse theory."[8] You are reusing ideas you have already learned to assist you in learning new ideas.)

Usually, at some level, a metaphor stops working. For example, space aliens shocking each other is a metaphor that doesn't explain synapses well if you look more closely. When a metaphor doesn't seem to work anymore, you can just throw it away. You can find a new metaphor to assist you in understanding more deeply. You can also use different metaphors to help you understand a single idea. That's just what we've done when we said that a connected set of neurons is like a set of brain-links, or like a mouse path in a forest.

A metaphor helps you understand a new idea by connecting it to something you already know. Whenever a metaphor doesn't work or breaks down, you can just throw it away and get a new one.

In our book, you'll meet many metaphors: zombies, links, mice, and octopuses. We use the metaphors to give you a better sense of the science. Remember, metaphors are just handy ways of helping you understand key ideas. Don't worry if your metaphor seems strange. Sometimes wackier metaphors open your mind to the new idea you're trying to learn. Wacky metaphors are usually memorable, too!

Now You Try! Understanding a Metaphor

We mentioned two metaphors:

- Wisdom is wealth.
- All the world's a stage.

Take a minute to think about these examples. Is their meaning clear to you? See if you can put these metaphors into other words. If not, you can check the endnotes for an explanation.[9]

Santiago Ramón y Cajal

So how did Santiago become such an incredible scientist?

It wasn't easy.

Santiago's dad realized that his son needed a different approach. His dad got him interested in medicine by showing him what real bodies looked like. How? The pair went off secretly at night to find bodies in graveyards. (This was back in the 1860s. They did things differently back then. Do not try this today!)

Santiago started drawing parts of the body. Being able to see, touch, and draw what he was learning about captured his interest.

Santiago decided to become a doctor. He went back to the mathematics and science studies he had missed when he was young. This time, he paid attention. He worked hard to build the proper trails in his brain that he hadn't built when he was younger.

He finally became a doctor! He was interested in all types of cells. So he decided to try to become a professor of pathology. (That's a professor who is an expert at telling the difference between healthy and sick body tissues. This is done by running tests on them that include looking at them closely through a microscope.) For this, Santiago had to pass an important test. He studied hard for a year. And he failed. So he studied hard for another year. And he failed again. He finally passed on the third attempt.

*Santiago Ramón y Cajal, always ahead of his time, shown here around 1870 taking one of the world's first selfies. (Note, you cannot see his right hand because it's pushing the button to take the picture.) Santiago cared a lot about young people. He even wrote a book for them—*Advice for a Young Investigator.

Santiago went on to draw beautiful pictures of all the neurons he saw through his microscope. His atlas of neurons is still the starting point for modern studies of neurons.

But there was a problem. Santiago wasn't a genius, and he knew it. He often wished he were smarter. He stumbled over his words, and he forgot details easily. But his research on neurons showed him that he could retrain his brain. Efforts to learn subjects like math and science gradually changed his abilities in those areas. By slow, steady practice, he could make new links—changing the structure of his brain. That's how he changed from a young troublemaker to a famous scientist!

Today's scientific research confirms what Santiago discovered. We can all "think" ourselves smarter. *Learning* makes us smarter. And learning how to learn is one of the best things you can do to get the ball rolling and make learning more successful. This is the most important idea in this book! So keep reading!

Later we'll meet Santiago again. And we'll discover more about why he could outthink geniuses—despite his "limited" brainpower.

Common Excuses in Learning[10]

It's easy to come up with excuses for why good learning techniques aren't for you. Here are the most common excuses—and how you can challenge them.

1. I don't have time.

If you don't take the time to work problems and read more slowly and carefully, you will not be able to grow new neural connections—which is the only way you learn. If you've quickly run your eyes over the material in a book, it's still just lying there on the page. It's not in your brain. *You haven't learned it*. This is why you really need to focus while you're doing a Pomodoro, rereading if necessary. It helps you make the best use of your valuable time.

2. I don't have a good imagination.

Creating metaphors and quirky pictures to help you remember might sound difficult. You may think that you don't have the same imagination that adults have. That's not true! The closer you are in years to your childhood, the more imagination you naturally have. You want to keep that childish imagination and build on it by using your imagination to help you learn.

3. What I'm learning is useless.

We don't normally have to do push-ups, pull-ups, or sit-ups in our everyday lives. But still, those exercises aren't useless—they help keep us in good physical shape. In a similar way, what we learn may be different from what we do in everyday life—but the new learning helps keep us in mental shape. More than that, new learning serves as a resource to help us transfer new ideas into our lives by using metaphor.

4. My teachers are really boring.

Your teachers give you some facts and ideas. But you are the one who must come up with a story that has meaning for you and will help make the concepts stick in your mind. The most boring thing would be if the teacher did all this work for you already, leaving you with nothing to do!

You are a critical part of the learning process. It's important for you to take responsibility for creating your understanding.

Pause and Recall

After you read this "Pause and Recall" section, close the book and look away. What were the main ideas of this chapter? Write down as many ideas as you can—you'll find that your neurons will fire better and you'll remember more easily if you're actively writing.

Don't worry if you can't recall much when you first try this. As you continue practicing this technique, you'll begin noticing changes in how you read and how much you recall. You might be surprised to learn that even distinguished professors will sometimes admit that they have trouble recalling the key ideas of what they've just read!

Check this box when you're done: ☐

Now You Try! Create Your Own Metaphor for Learning

We'd like you to think about your latest learning challenge—whether it's in math, language, history, or chemistry. Try to come up with a good metaphor for what you're learning. Explain your metaphor to one of your friends. Remember—using a metaphor is really just finding a way to connect your new learning to something you already know.

A good way to come up with a metaphor is to take out a sheet of paper and begin doodling. Surprisingly helpful ideas can emerge from silly doodles!

Here are a few examples to get you started:

- If you are learning about electrons, you might think of them as tiny fuzzy balls. Flowing electrons make an electrical current, just like flowing water molecules create a water current.
- You might think of history as having "streams" of different factors that all contribute to historical events like the French Revolution or the development of the automobile engine.
- In algebra, you can think of x as being a rabbit that pops out of the hole only when you solve the equation.

Key Terms Related to Neuroscience

Axon: An *axon* is like the "arm" of a neuron. It reaches out toward the next neuron in a *set of brain-links.*

Brain-links: A *set of brain-links* is a term used in this book to indicate neurons that have become part of a team by frequent "sparks" across *synapses.* Learning something new means creating new *brain-links.*

Dendrite: *Dendrites* are like the "legs" of a neuron. The *dendritic spines* on the dendrite receive signals from other neurons and can pass them along the dendrite toward the main body of the cell (the neuron-alien's "eye").

Dendritic spine: *Dendritic spines* are the "toes" that stick out of a dendrite (a "leg" of the neuron). Dendritic spines form one side of a synaptic connection.

Diffuse mode: We use the term *diffuse mode* to mean that certain parts of your brain become active when you're resting and not thinking about anything in particular. (Neuroscientists call this the "default mode network," the "task negative network," or the "activation of neural resting states.")

Focused mode: We use the term *focused mode* to mean that certain parts of your brain go to work when you pay close attention to something. When you are focusing, the active parts of your brain are mostly different from those parts that are active in the diffuse mode. (Instead of "focused mode," neuroscientists use the heavy-duty term "activation of task positive networks.")

Neuron: *Neurons* are tiny cells that are key building blocks of your brain. Your thoughts are formed by electrical signals that travel through neurons. In this book, we say that a neuron has "legs" (dendrites) and an "arm" (an axon), almost like a space alien. An electrical signal can travel from the neuron's legs to its arm, where it can "shock" the next neuron in a set of links.

Neuroplasticity: The fact that trails in your brain can change and grow is called *neuroplasticity*. Your neurons are like plastic clay you can mold. You can change your brain through learning!

Synapse: A synapse is a special, very narrow gap between neurons. Electrical signals (your thoughts) can jump across this gap with the help of certain chemicals. When we say a "stronger synapse," we mean that the effect of the signal jumping across the gap is stronger.

SUMMING IT UP

- Neurons send **signals** that flow through your brain. These signals are your thoughts.
- Neurons have a distinctive look, almost like space aliens. There are ***dendrites*** ("legs") on one side of the neuron and an ***axon*** ("arm") on the other.
- ***Dendritic spines*** are like "toes" on a neuron's "legs."
- **The axon of one neuron "shocks" a dendritic spine on the next neuron.** This is how one neuron sends a signal to the next neuron.
- **The word *synapse* refers to the special narrow gap where the axon and the dendritic spine are nearly touching one another.** A "spark" is sent from the axon to the dendritic spine.

- **Metaphors are powerful learning tools.** They help us reuse neuron trails we have already developed so that we can learn more quickly.
- **If a metaphor is no longer useful, throw it away and get a new one.**
- In our book, we point out that a set of brain-links (or mouse paths) can grow stronger in two ways:
    - **Each synapse gets bigger,** so each spark is stronger.
    - **More neurons join in,** so there are more synapses.
- **You strengthen your brain-links (or mouse paths) by practicing.**
- It's easy to come up with excuses for why good learning techniques aren't for you. **It's important to challenge these excuses.**
- **Even kids who start out badly at school can turn things around and end up being successful.** Remember Santiago Ramón y Cajal, the father of modern neuroscience!

CHECK YOUR UNDERSTANDING

Have the key ideas of this chapter slipped into your brain? Answer the following questions.

1. The _______________ that neurons send to other neurons form your _______________. (Fill in the blanks with the best words.)

2. From memory, draw a picture of a neuron. Label the key parts. Try to do this first without looking back at the picture. *Active recall* instead of just looking at the answer. That's what helps the new set of brain-links to grow!
3. Does an axon shock a dendritic spine? Or does a dendritic spine shock an axon? In other words, does the signal go from the axon to the dendritic spine? Or the other way around?
4. What do you do when a metaphor breaks down and doesn't work anymore?
5. Why did scientists think that your brain was made of one single neuron network instead of thinking that there were many smaller neurons that sent signals to each other across tiny gaps?
6. What is a "set of brain-links"?
7. How is a "thought" similar to a mouse in a forest?
8. When you learn something new, you form a new set of _______________ in your brain. (Several different words could be used here.)

(When you're done, you can compare your answers with the ones at the back of the book.)

Picture walk done and notebook ready for the next chapter? ☐

CHAPTER 5

THE OTHER SIDE OF THE TEACHER'S DESK

Hi. I'm Al. Pleased to meet you. I'm helping Barb and Terry write this book. Sometimes professors use big words and long sentences. I'm here to keep an eye on the language!

I'm forty-two years old, but this summer I found myself sitting nervously in an exam hall with a group of sixteen-year-old students. I was working on a chemistry test. I was the only adult in there. Why? Had I been held back twenty-six years? . . .

I'll explain.

I teach at a school in England. It's a really nice, friendly school. You would like it. But I teach religion and philosophy. Not chemistry.

In fact, until a year ago, I knew nothing about chemistry at all. I went to a good school when I was younger, but I didn't like science. It was hard. You had to learn a lot of material. When I was young, I wasn't interested, and school let me drop it.

I found languages were easy and fun for me, so I did lots of those. That meant I could give up the stuff I found difficult. Like chemistry.

"Phew," I thought at the time. What a relief. I believed my school was doing me a big favor. I didn't have to struggle with something tough.

But since then, I have often felt that there was something big missing from my education.

Hair today, gone tomorrow— me before I understood atoms.

Part of my job now is to watch other teachers in their classes, and to talk to them about how they teach and how to improve. Are they able to help the students understand algebra, or World War I, or how to hit a ball? How should they deal with the kid who won't listen and keeps poking his friend with a pencil?

I've seen quite a few chemistry classes, and I always felt a little embarrassed. I couldn't understand what was going on. They used language that I didn't understand. They knew how to mix substances I had never heard of.

Students sometimes asked me questions in those chemistry classes. They thought that because I was a teacher, and since this was just "basic" chemistry, I should know the answers. I could never help them, and they were a little shocked. After all, if I didn't know anything about atoms, how could I help the chemistry teacher?

I used to laugh it off. But it didn't feel good to have such a big hole in my knowledge of the universe.

Then I met Barb. This was a couple of years ago in England. She had come to share her story with my school. I found it really inspiring and relevant to me. Like me, she had been a "language person," but she realized that she could broaden her passions. She didn't allow herself to be limited to the things she liked and found easier. She told us that we could rewire our brains, which I didn't know (because I had studied so little science).

I then decided to learn high school chemistry. And I decided to do it the Barb and Terry way. I read Barb's book *A Mind for Numbers*, and I took Barb and Terry's online course, Learning How to Learn. They taught me the same tips and tricks about learning that we're teaching you in this book.

I announced to my whole school that I was going to do this. I was going to take the five-year high school chemistry exam with them that summer. And I wanted them to help me.

Normally I taught them. Now I wanted them to teach me.

The best time to plant a tree is twenty years ago. The second best time is now.

—Thought to be a Chinese proverb

Students were a great help to me when I was trying to learn chemistry.

The students at my school found it funny that I was doing this. Some asked what the point was. I didn't *need* to learn chemistry for my job. I explained that I just wanted to know more about the world. And I wanted to share with them the new lessons I had learned about learning from Barb and Terry. I thought this would help them, too. And I thought it would make me a better teacher because I would remember what it was like to be a student.

My students were encouraging and amazing at helping me. They often asked me, "How's the chemistry going, Al?" as I walked around the school. The reminders would prompt me to do a Pomodoro. They recommended websites and study guides. They quizzed me on the basics. When I turned up in their chemistry classes, they would invite me to join them and their lab partners in doing experiments. And they were patient at explaining the simple things to me when I got stuck. They could have laughed at me, but they didn't. Students make great teachers.

I followed Barb and Terry's advice as much as I could. I worked in 25-minute bursts. I deliberately mixed focused sessions with diffuse breaks.

Breaks usually meant walking my dog, Violet. Terry had told me how useful exercise was for him. It worked for me, too. Sometimes I explained chemistry concepts to Violet as we walked. Teaching others is a great way to learn, even if your student is a dog!

Violet sometimes had a little trouble understanding what I was explaining to her.

I would actively *recall* key information. I tested myself after each new section by working on test problems. When I didn't understand something from the book at first, I would look for videos on the internet—being careful not to get distracted. If that didn't work, I would ask one of my students. They usually knew the answer, and I knew it was good for them to teach me. It was a win-win situation.

I remembered to *interleave* by switching topics. (You'll learn more about that soon.) I looked ahead in chapters to get a sense of what was coming. I looked at old exams so I knew the kinds of things the teachers would ask. I made up zany images in my head to remember difficult material. For example, I imagined myself *crying* over a melting *white* Porsche car. This helped me to remember that the catalyst for melting aluminum is *cryolite* ("cry-a-lot"), which is a *white* powder. It worked for me . . .

I had to make sacrifices to do all this in a year, which I had promised my students I would do. I have a busy job, so I spent school vacations and some weekends studying chemistry. My family thought I was crazy. But I enjoyed getting rid of my ignorance. And I loved having a method that worked. I could feel that I was making progress.

When the exam came, I thought I would do okay, but I wasn't confident. I had done as much work as I could in one year, but most students worked on it for *five* years before taking the exam. I wished I had practiced even more. How strong were the trails on my mental pinball table?

The exam was fair. Some of it was tough, but most of it allowed me to show what I could do. When I finished, I felt like I had given it my best shot.

I had to wait eight weeks to find out my results. Like my students, I was nervous on results day. When I opened my envelope, I was really happy with it! I had passed with a good grade, and I was able to tell my students without feeling embarrassed. They shared my joy in having succeeded.

I'm really glad I did it. It allowed me to have lots of great conversations with students about learning, and I was able to share Barb and Terry's insights with them. It reminded me what it was like to be a student and to have to struggle with difficult material. Teachers often forget this because they're experts in their subjects. They sometimes don't understand why kids find things difficult. It's good to be reminded that beginners usually do find things tough! The best part was feeling like I was sharing an experience with my students. I understand their world better now, as well as understanding atoms. And I've learned some great lessons about how, together, we can become better learners.

I think a lot of adults would benefit from doing something like this. Especially those who work with young people or just spend time with them. Why don't you challenge one of your teachers to learn something new? Or your mom or dad? Offer to help them. That way you can have great conversations with them about how to be a good learner. And they will understand your world better, too.

Pause and Recall

Get up and take a little break—get a glass of water or snack, or pretend you're an electron and orbit a nearby table. As you move, see if you can recall the main ideas of this chapter.

Check this box when you're done: ☐

Now You Try! Taking a Break

Al McConville found that taking diffuse breaks between his Pomodoros helped him to learn.

Take out a sheet of paper and make a list of favorite activities that work for you when you are taking your diffuse breaks. If you'd like, ask a friend to do the same thing. Then compare your lists.

SUMMING IT UP

- **It's possible to learn new subjects that you never thought you could learn.** You can do this even when you are an adult!
- **Learning about new subjects can empower you.**
- **Use tools like the Pomodoro and active recall, and be sure to exercise** (you'll learn more about that soon!) to boost your learning.
- **Check the internet** for other explanations if the first explanation doesn't make sense to you.
- **Ask other people for help when you are stuck.**
- **Don't be afraid to go back to a beginner's level,** even if you are older than other students.

Picture walk done, a few end-of-chapter questions tackled, and notebook ready for the next chapter? ☐