SO, HOW DOES YOUR BRAIN WORK?

By

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WHAT'S IN YOUR HEAD?

Research shows that students learn more effectively when they understand how their brains work. How much do you know about what actually happens physiologically (physically) in your brain when you learn? As a scientist, you're probably curious to know how your brain works. The brain is complex and still not fully understood, but this chapter explains some important brain facts. If you have a better understanding of how your brain works, you can take advantage of how your brain works, making you a more effective and efficient student.

NEUROPLASTICITY AND BRAIN GROWTH

Your brain contains billions of neurons (brain cells) that communicate with each other through trillions of synapses (connections between neurons). If two neurons interact repeatedly, they form a stronger connection that allows them to transmit messages more easily and accurately – this is what learning is. This ability of your brain to change is called neuroplasticity. There are three things that you should know about this process:

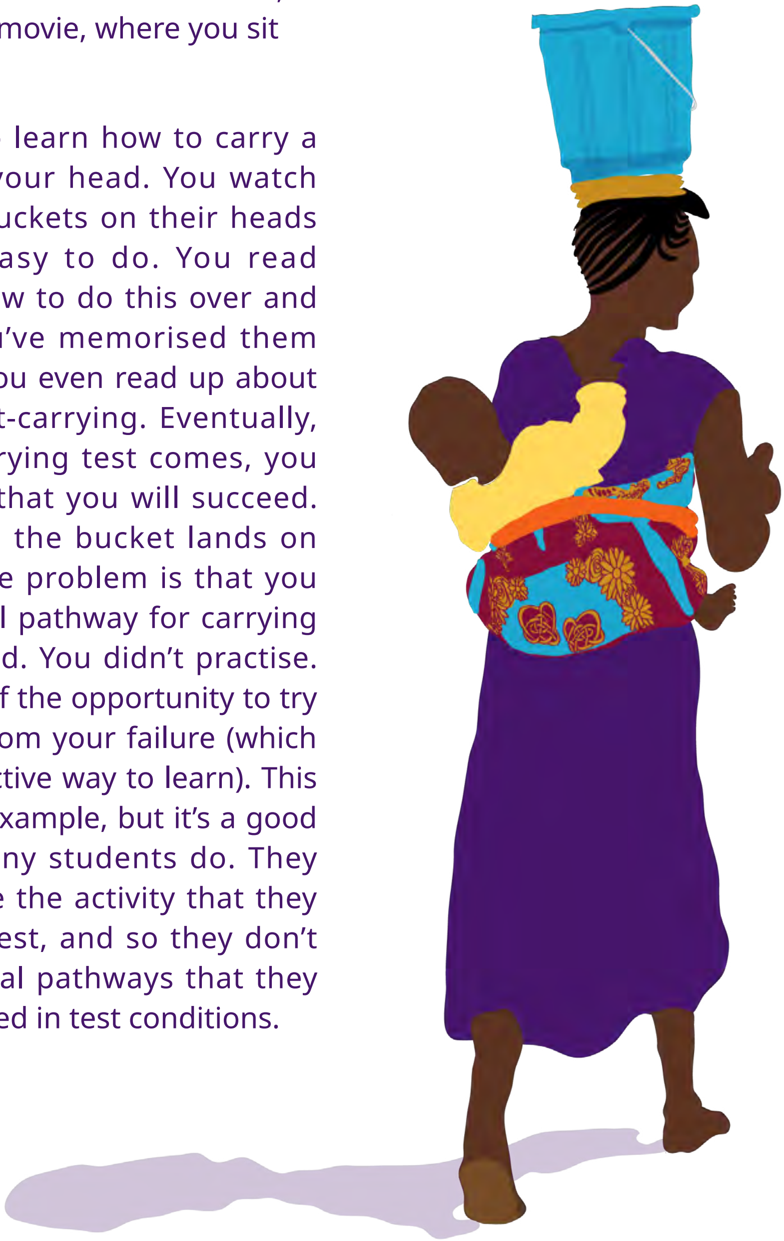
1. Neuroplasticity means that your intelligence and talents are not fixed, but instead grow as you study. What you can do now is just your starting point for learning.

2. New pathways between neurons build on existing pathways between neurons. You learn by connecting new knowledge to existing knowledge, regardless of whether you intend to.

3. To learn, you need to use these new neural pathways. Learning involves active mental engagement, such as trying things out for yourself or making a mind map of a lecture. This is different from entertainment, like watching a movie, where you sit passively.

Your brain grows new neurons in two ways: through learning and through physical exercise.

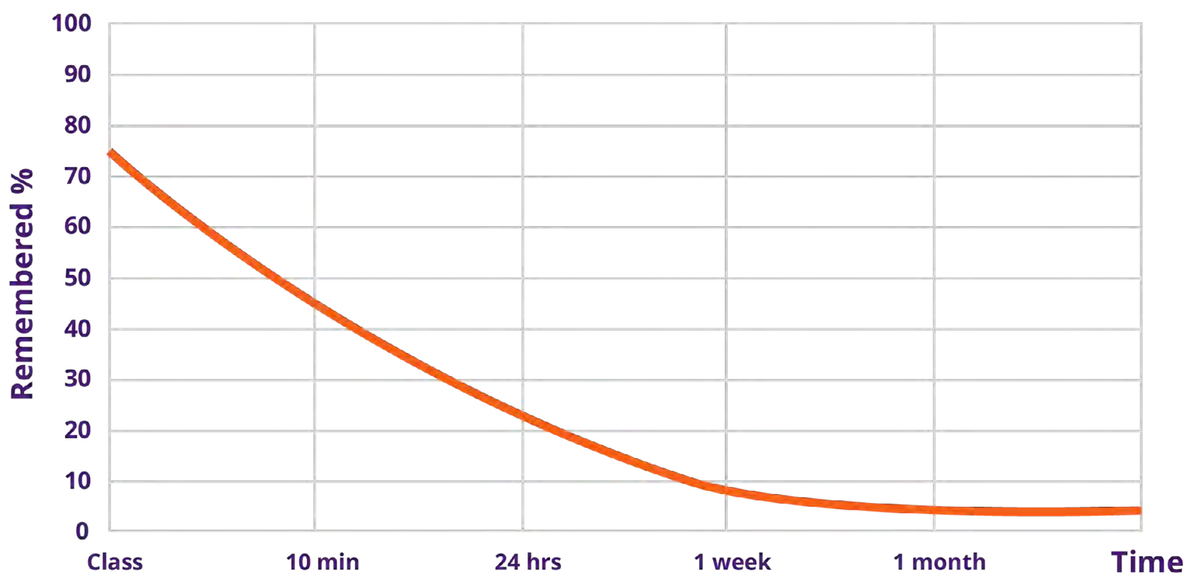
Suppose you want to learn how to carry a bucket of water on your head. You watch other people carry buckets on their heads – it seems pretty easy to do. You read instructions about how to do this over and over again, until you've memorised them off by heart. Maybe you even read up about the physics of bucket-carrying. Eventually, when the bucket-carrying test comes, you are pretty confident that you will succeed. But you fail the test: the bucket lands on the ground. Why? The problem is that you didn't build the neural pathway for carrying a bucket on your head. You didn't practise. You didn't give yourself the opportunity to try and fail – and learn from your failure (which is often the most effective way to learn). This may seem like a silly example, but it's a good analogy for what many students do. They don't actually practise the activity that they will have to do in a test, and so they don't have the strong neural pathways that they need in order to succeed in test conditions.



THE FORGETTING CURVE AND SPACED REPETITION

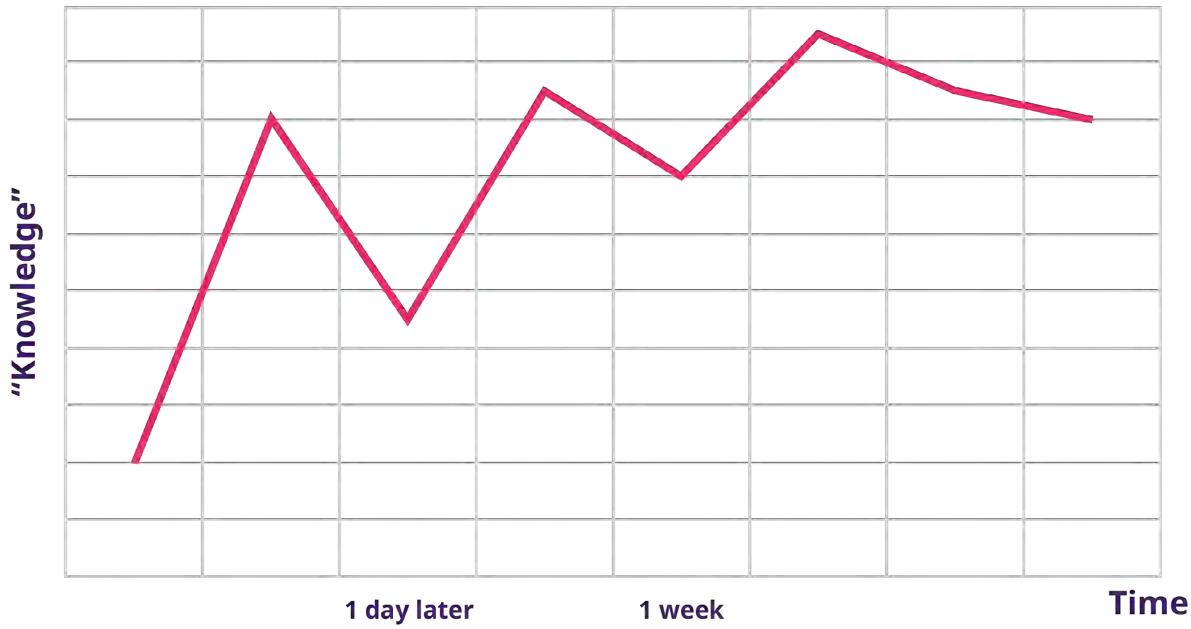
As you probably know, memory plays a key part in the learning process. Figure 1 is a representation of the 'forgetting curve'. This graph shows how much new information a person remembers as time progresses. As a scientist, you should be able to interpret graphs, so let's see how you fare with this one. The data from the original study is that within an hour, people tend to forget up to 50%. Within 24 hours, this can increase to 70%. By the end of the week, people tend to retain only about 25% of what they've learnt.

Figure 1: The forgetting curve – percentage remembered versus time elapsed



What's the point of attending lectures if all you do is forget! The good news is that it's possible to stop forgetting by reminding yourself of what you've learnt. Figure 2 shows what happens if you remind yourself regularly about what you've learnt.

Figure 2: Retention with spaced repetition



Pause to ponder

What do you notice about this graph? How would you describe this graph to someone who can't see it?

Each time you review your work, you interrupt the forgetting curve and reach a new retention peak. Do you notice that each time you review your work, the peak is higher? This is because you understand more than you did originally. Also, each time, the forgetting curve is less steep. This kind of learning is called 'spaced repetition'. Research shows that spaced repetition is the most effective way to learn. If you've ever tried to learn a new skill, like playing a musical instrument, you'll know that this approach works.

The forgetting curve can be a disaster when you're learning a hierarchical subject (like any of the sciences), where each lecture builds on the previous one. Spaced repetition is, therefore, a particularly important learning technique for science students. Also, work involving higher Bloom's levels (such as *application* and *analysis*) needs to be spaced out to allow new neural connections to solidify. Since science is TOUGH, you will need an approach that strengthens your neural connections with the least overall effort. Learning 'a little often' beats learning 'a lot all at once'!

'Eat the frog first'; start doing the work that you struggle with first so that it can be easier to complete your other tasks.

LONG-TERM AND WORKING MEMORY: RECOGNITION VERSUS RETRIEVAL

Once you've learnt something, it forms a solid neural connection that becomes part of your **long-term memory**. You can think of your long-term memory as a library with everything you know. In order to use that information, you need to retrieve it into your **working memory**. You can think of retrieval as taking a book out of the library.

However, there are two problems with this. The first problem is that, even though you may 'know' something (insofar as you would recognise it if you saw it in a book), you may have difficulty retrieving it, which is what you need to do in a test. *Recognition* is not the same neural process as *retrieval*, so you need good strategies for retrieving information (which we provide later in this chapter).

The second problem is that working memory is limited in size – some experts say it can only manage four things at once. This means your cognitive processes are weakened when you multitask. You can help your working memory by offloading onto paper, rather than trying to hold everything in your head at once. This is where your lecture notes help.

If you're wondering whether short-term memory is the same as working memory: they are interrelated. Your short-term memory allows you to remember a small set of numbers for a short time, but your working memory enables you to manipulate those numbers (e.g. by adding or rearranging them).

DIFFUSE VERSUS FOCUSSED THINKING

Have you ever been stuck on a problem, then got up to do something else and suddenly realised the solution to the problem? This happens because your brain has two modes when it comes to thinking: focussed and diffuse [1].

- **Focussed thinking:** You use your brain intensely to do a task. Your brain uses a small number of concepts, manipulating them in your working memory.

- **Diffuse thinking:** You're not concentrating on a task. Your subconscious works in the background, wandering freely. In this mode, your brain often connects information that you didn't think was relevant, but is actually critical for solving the problem.

So, how can you make the most of diffuse thinking? First, recognise when you are stuck on a problem and get up – you can stretch or tidy your room. Second, apply the Pomodoro Technique, in which you use a timer on your computer or phone to give yourself a study streak of 25 minutes of focussed thinking, followed by 5 minutes of diffuse thinking when you give yourself a reward for the 25 minutes study streak you just did. Diffuse thinking can also happen while walking, catching a shuttle or standing in a queue, if it follows a study streak.

Maṅa a mutukana a si vhumatshelo hawe.
One's background does not determine what one's future looks like.

Mphaka Rofuluphela

NEURODIVERSITY

Neurodiversity is so important that is has a chapter of its own, but let's talk about it briefly here – particularly in terms of how it relates to your brain's functioning.

In a nutshell, neurodiversity refers to the small differences that make each of our brains work differently. We all perceive and relate to the world differently. This is a good thing – there is **value** in the different ways we perceive and think and feel and act in the world. These differences are thought to come from the differences in our **brain's physiology** and **development**, right down to a cellular level. **Specific genes** are used to make **specific proteins** by **specific cells** in **specific regions** in your brain.

Think of it this way: each thought you have can be traced as a **biochemical signal** between synapses; each feeling and emotion you experience comes from dozens of chemical signals and their **receptors** that float around each neuron! And each of these processes vary slightly between each person, which basically means that there are an infinite number of brain types out there.

Much of what we spoke about in this chapter holds true for everyone, but you must be aware that what may work for you might not work for another because of neurodiversity.

THE VITAL ROLE OF SLEEP IN LEARNING

Sleep is not only essential to your well-being; it also plays an essential role in your learning. What happens when you sleep? For starters, your brain gets a wash: cerebrospinal fluid flows through your brain and clears out toxins. This can't happen while you're awake, so sleep is vital for brain hygiene and health. There are two kinds of sleep: REM (rapid eye movement) sleep and non-REM sleep. During REM sleep, your brain consolidates everything that you have learnt that day. During your dreams in REM sleep, your brain practises its new neural pathways. During non-REM sleep, your physical body repairs itself, which is why sleep strengthens your immunity. During the night, you alternate between REM and non-REM sleep, with the proportion of REM sleep gradually increasing. If you sleep for six hours, you lose out on

40 % of the REM sleep that you get in eight hours – you can see that even losing two hours of sleep drastically reduces your learning ability.
Research shows that sleep deprivation has measurable neurological effects: it reduces the speed and strength at which your neurons fire, which impairs your cognitive ability. It also shows that sleep-deprived people think they're doing better than they really are (similar to people who've drunk too much alcohol) and that sleep deprivation affects your mental well-being.

What can you conclude from the above? It seems that sufficient sleep is vitally important for learning, in three ways. Firstly, when you are sufficiently rested, learning is easier because your brain works better at a neurological level. Secondly, sufficient rest contributes to your physical and mental well-being, which makes it easier to learn (it's hard to learn when you're sick or depressed!). Thirdly, learning continues while you sleep – when you're asleep, your brain is not. Working smart means getting sufficient sleep. In contrast, sleep deprivation is literally 'working stupid', as your brain doesn't function properly and much of your study time is wasted if your learning isn't consolidated while you sleep.

If you need an alarm clock to wake you up, you're not getting enough sleep.

HOW TO MAKE THE MOST OF HOW YOUR BRAIN WORKS

This chapter is full of good news! Your brain is at work even when you are not. Your brain engages in learning processes while you are sleeping, exercising and not concentrating. Now it's up to you to make the most of how your brain works. Studying smart means having a routine that includes:

- Regular exercise to grow more neurons.
- Regular breaks to take advantage of diffuse thinking.
- Eight hours of sleep every night for your brain to strengthen neural pathways and for your brain to work well when you're actively studying.
- Daily and weekly review of lecture content.

READ/WATCH MORE

How your brain works

- **How the brain learns:** Watch this four-minute **video** for more details on how neurons communicate.

- **Growth mindset:** Students have a 'growth' or a 'fixed' mindset, depending on whether they think that intelligence can grow or is fixed. This affects how they behave. **Read more** (in particular, scroll down to Figure 2.11).

- **The role of sleep:** Read the American Academy of Sleep Medicine's article on research that leads to them to conclude that **students getting enough sleep is vital to academic success**.

REFERENCE

[1] Oakley, B. 2014. *A mind for numbers: How to excel at math and science (even if you flunked algebra).* New York: Penguin Random House.

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