Night School

Richard Wiseman | 38 minutes reading time

Lesson 1

INTO THE NIGHT

Where we find out what happens to your brain and body every night of your life, discover how to overcome jet lag, and learn the ‘ninety-minute rule’.

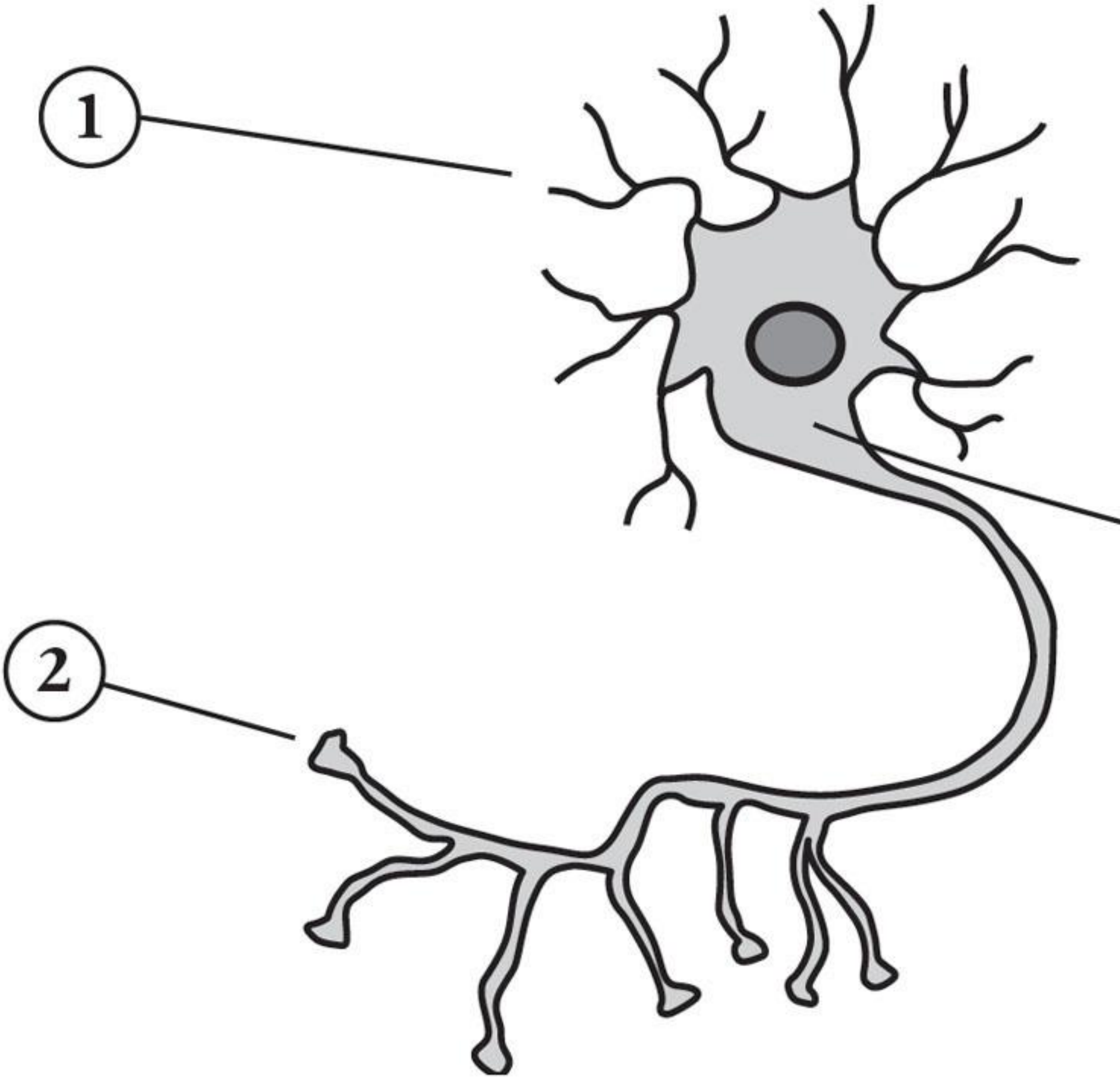
Welcome to your first day at Night School. In this lesson we will explore two ideas that underpin the whole of sleep science and, in doing so, find out what happens to your brain and body every night of your life. We begin by examining the electricity coursing through your brain right now, then we’ll meet an eccentric German professor who spent his life attempting to prove the existence of telepathy, and finally we’ll spend the night in a modern-day sleep laboratory.

The personification of static

I would like to start by telling you something that has been playing on my mind for quite some time. You are amazing. There, I’ve said it and there’s no going back. However, before you start to feel overly smug, there’s something else that I need to say. I think your closest friend is amazing too. In fact, I think that everyone you know is remarkable (except for John in Accounts, who is actually quite annoying). And why are you all so jaw-droppingly wonderful? Because each of you owns one of the most wondrous, and complex, objects in the universe. This object has cured disease, put men on the moon, and created breathtaking works of art. It allows you to see the world and listen to music, to make momentous decisions and move around, to laugh and to love. This remarkable object is sitting between your ears at the moment, quietly whirring away and allowing you to read this sentence. I am, of course, referring to your brain. (If you hadn’t figured that out by now, I retract my initial compliment.)

Although everyone has a brain, most people are unaware that their mind runs on electricity.

If you were to slice off the top of someone’s skull you would come face-to-face with what appears to be a large lump of pink jelly. Study any section of this strange substance under a high-powered microscope and you will find that it’s made up of lots of tiny cells called ‘neurons’ (see the diagram of a neuron). Each neuron consists of three main sections – (1) ‘dendrites’, finger-like fibres that receive signals from other cells; (2), ‘axons’, which pass signals to other cells; and (3) a ‘cell body’, which controls everything. Together, these deceptively simple cells are responsible for every thought that has crossed your mind and every emotion that you have experienced.



Neurons are little electronic messaging systems. When the dendrites receive a signal from a neighbouring neuron, the cell body springs into action and sends a tiny electronic pulse down its axon and on to the surrounding cells. These electronic messages are zipping around your head at this very moment, sometimes at speeds in excess of 200 miles per hour. Neuroscientists now believe that there are about 20 billion neurons in the average brain, and more than 160 trillion connections between them. Although any one neuron only creates a tiny amount of electricity, their combined output is considerable, with the average brain generating enough energy to power a 20-watt light bulb.

Around the turn of the last century, scientists were aware that the brain ran on electricity, but couldn’t figure out a way of measuring the tiny signals produced by groups of neurons. Enter the most curious of men, Dr Hans Berger.

Born in Germany in 1873, Berger's life changed forever when he had a close encounter with a cannon. Berger had enlisted for the cavalry service in his twenties. During training, he was thrown from his not-so-trusty steed and landed in the path of a horse-drawn cannon. The driver of the artillery battery carried out a textbook emergency stop which left Berger badly shaken but unhurt. At the precise moment of the accident, Berger's sister had had a strange feeling that her brother was in danger and sent a telegram asking if he was OK. This was the only telegram that Berger had ever received from his family, and he struggled to write off the experience as a coincidence. Instead, Berger became convinced that the spooky event was proof of telepathy, and devoted his life to discovering how thoughts can travel from one mind to another.

Working alone, Berger was desperate to develop what he referred to as a 'brain mirror' – a system of sensors that could be placed on the scalp and used to measure the tiny amounts of electricity being generated by the neurons inside the skull. Berger's experiments were as time-consuming as they were frustrating, but he locked himself away in his laboratory and persevered in the face of failure (Diary entry, 1910: 'Eight years! Trying always, time and again.'). The German professor grew increasingly distant from his colleagues and came to be seen as a deranged madman. To devote as much time to his research as possible, Berger ensured that his life was highly automated and predictable, with one of his colleagues later noting Berger 'never overlooked a deviation from established routine . . . His days resembled one another like two drops of water. Year after year he delivered the same lectures. He was the personification of static.'

After two decades of disappointment, Berger made a series of technological breakthroughs that hinted at success (Diary entry, 1924: 'Is it possible that I might fulfill the plan I have cherished for over twenty years?'). After spending several more years refining his invention, Berger finally announced that he was able to reliably record brainwaves, and demonstrated the world's first fully functioning electroencephalogram (or 'EEG machine' for short).

Unfortunately, the academic community adopted a somewhat closed-minded response to Berger's invention. Convinced that it was impossible to detect such tiny amounts of electrical activity from sensors placed on the scalp, many of Berger's colleagues assumed that his findings were due to either error or fraud. After retiring from academia in 1938, Berger's health quickly deteriorated and he became deeply depressed. The maverick measurer of minds eventually took his own life in 1941, hanging himself in hospital.

Berger didn't ever prove the existence of telepathy. Instead, he left a far more wondrous and tangible legacy. Academics across the world eventually realized that he had made a genuine breakthrough, and began to take a closer look at his remarkable invention. One of the first in the queue was a Wall Street tycoon and eccentric researcher named Alfred Lee Loomis.

The palace of science

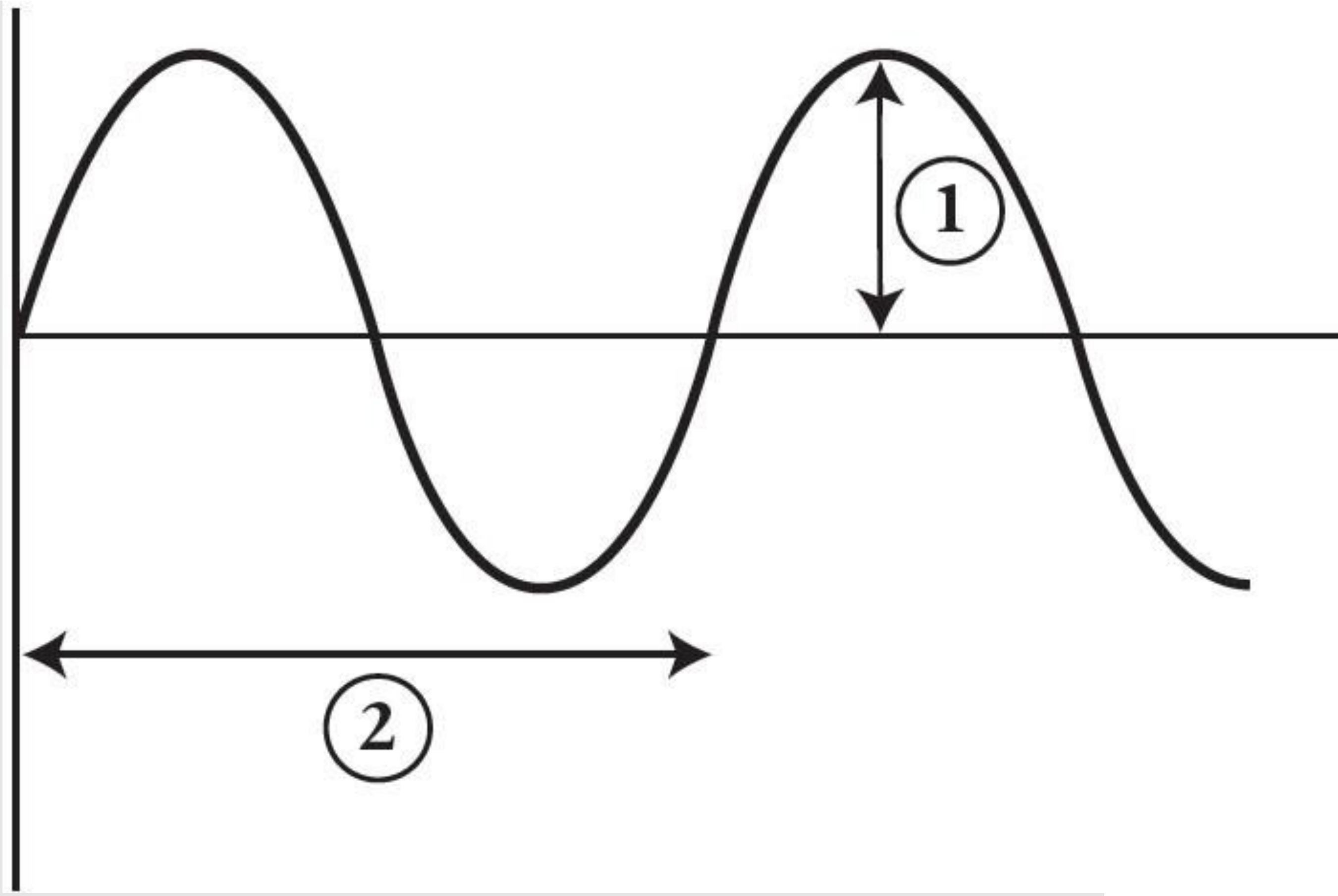
Born in 1887, Loomis was both an amazingly successful investment banker and the last of the great amateur scientists. As a child, Loomis was fascinated by puzzles, chess, and conjuring. As a young man he developed a passion for science, and eventually struck up a close working relationship with a well-known experimental physicist from Johns Hopkins University named Robert Wood. It was an odd but productive collaboration. At one point, for example, Wood built a large ‘spectrograph’ (a device designed to disperse radiation into a spectrum) in his barn, but discovered that the instrument’s forty-foot tube was frequently ineffective because it became filled with spider webs. Wood and Loomis eventually came up with a strange but highly effective solution to the problem. Whenever the spectrograph became blocked, the intrepid duo would drop a cat in one end of the tube and place some food at the other end. As the cat made its way towards the food, its fur acted like a huge duster and removed the cobwebs.

Loomis enjoyed his time in the barn and eventually decided to build his own private research institute. In the 1920s, he bought a large mansion in New York State, and set about creating his ‘palace of science’. Over the next decade, he fitted out his mansion with cutting-edge technology, and played host to some of the world’s best-known scientists, including Niels Bohr, Guglielmo Marconi, and Albert Einstein. Loomis made several important scientific and technological discoveries, including playing a key role in the development of radar, inventing a new way of measuring the muzzle velocities of guns, and helping to create ground-controlled approach systems for aircraft.

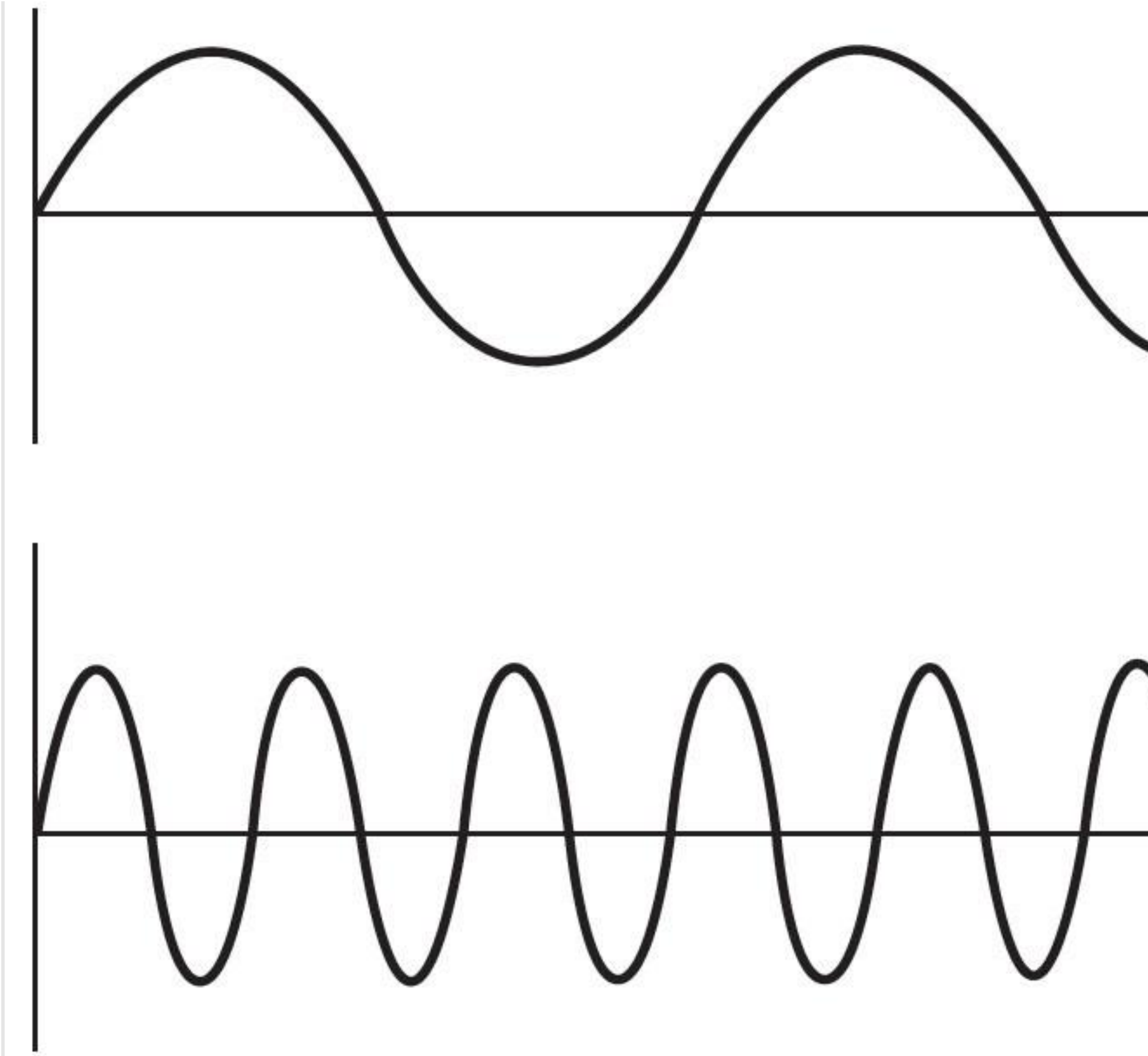
In the mid-1930s, Loomis heard about Hans Berger’s remarkable invention and wondered whether it could be used to investigate sleep. He constructed his own EEG machine, and invited overnight visitors to his palace of science to have their brains monitored. Within a year, Loomis discovered that people’s brains are not dormant when they are asleep but instead produce a small number of distinct types of waves. Additional work revealed that these waves occur in a highly predictable pattern throughout the night (we will discover more about this pattern later in this lesson). Although identifying these different stages of sleep was a remarkable step forwards, one final mystery remained. This last piece of the puzzle only fell into place twenty years later, and was the result of one of the most important experiments conducted in the twentieth century.

What’s in a wave?

The brainwaves that are detected by EEG machines have two main features: amplitude and frequency. Both of these features are illustrated in the following diagram.

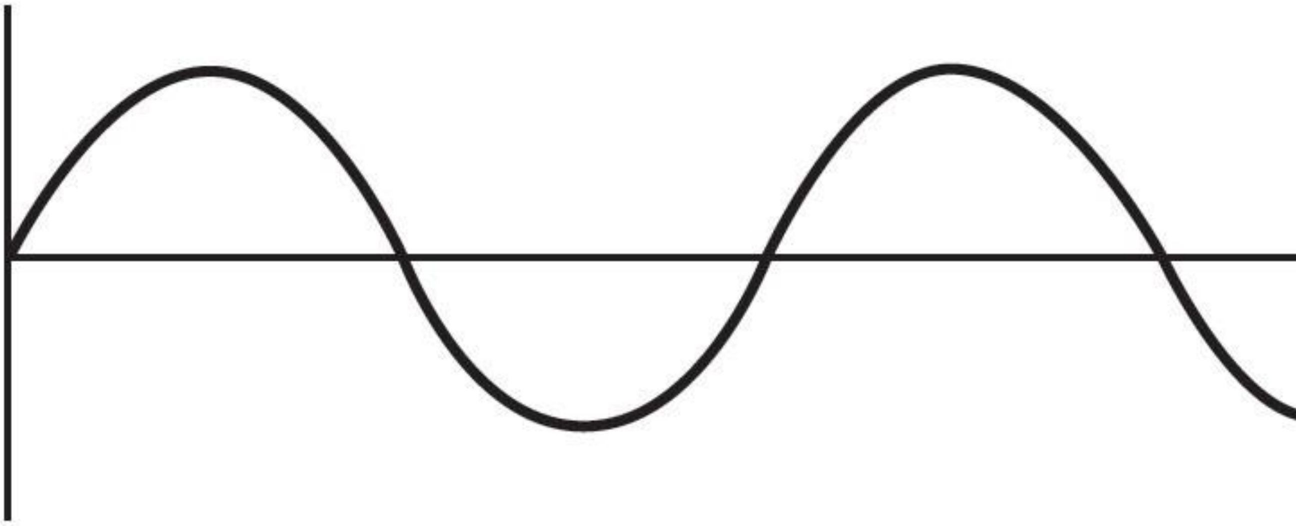


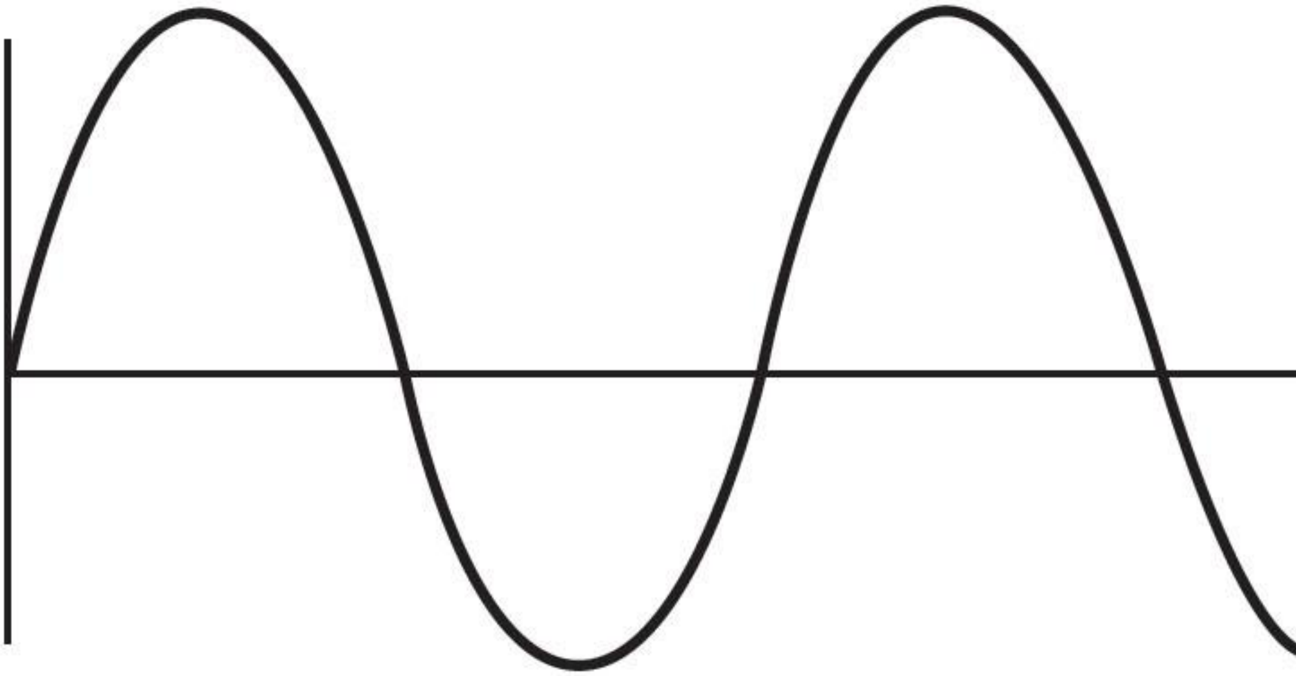
The amplitude (1) is simply the maximum amount of energy the wave has, and the frequency (2) is the number of times that the wave repeats each second. The frequency is usually measured in units referred to as hertz, or ‘Hz’ for short. To understand the difference between amplitude and frequency, it’s helpful to sing a little song. Please sing ‘Laaaa’ in a deep voice. You have just produced a low-frequency note that would look something like the top line in the following diagram.



Now please sing ‘Laaaa’ again, but this time in a much higher pitch. If you were to plot the frequency of your voice now, you would get something that resembles the lower line in the diagram above.

Finally, try producing two more ‘Laaaaa’s, ensuring that they are the same pitch, but that one is much louder than the other. This time you are changing the amplitude of the wave, rather than the frequency, and so the quieter note would look like the top line in the diagram below, while the louder one would look like the bottom line.





It’s the same with brainwaves. Each brainwave can be classified according to the degree to which it is ‘loud’ or ‘quiet’, and ‘low’ or ‘high’. In principle, this could result in millions of different kinds of waves. However, in practice, your sleeping and dreaming brain only produces a handful of different waves. For instance, when you are wide awake your brain creates ‘beta waves’. There are about twelve to thirty of these waves produced each second, and so they show up on an EEG graph as rapidly changing squiggles.

When you relax, the frequency of these waves suddenly slows down until there are only about eight waves each second. The resulting waveform is referred to as an ‘alpha wave’ or ‘Berger Wave’ (named in honour of Hans Berger). During sleep, these waves become slower still, and we will take a closer look at each of the waveforms associated with the different stages of sleep later.

How to draw blood from a turnip

In 1951, Eugene Aserinsky was having a tough time of it. Aged thirty, he was struggling to provide for his wife and son, with the entire family living in a small Chicago apartment heated by a single kerosene stove. Aserinsky had had an odd career path. After excelling at school he had skipped from college to college studying everything from Spanish to dentistry, failing to focus. He left education without a degree and found work as a high explosives handler in the army. After spending time taking his life in his hands, he decided to return to college. At the time, the University of Chicago had a reputation for accepting students with unusual backgrounds, and the unconventional Aserinsky was eventually enrolled in their physiology graduate programme.

When he arrived, he was less than delighted to discover that the only available academic advisor was an infamous and eccentric professor named Nathaniel Kleitman. The Russian-born Kleitman had dedicated his life to researching the science of sleep. In 1939 he had reviewed more than 1,000 scientific papers on the topic and written the then-bible of sleep research, *Sleep and Wakefulness as Alternating Phases in the Cycle of Existence*. Kleitman had also gained a considerable reputation for acting as his own guinea pig in the most challenging of conditions. In one series of studies, for instance, he had investigated how sunlight influenced sleep by spending a month in a large rock chamber deep within Kentucky’s Mammoth Cave, by living on a submarine, and by exposing himself to almost continuous sunlight above the Arctic Circle. These endurance studies appear to have caused little long-term harm, with Kleitman dying at the ripe old age of 104 in 1999.

Kleitman met with Aserinsky and suggested that he study the way in which babies blink when they fall asleep. Aserinsky found his endless observation of babies as ‘exciting as warm milk’ and, after spending months trying to ‘draw blood from this research turnip’, decided to call it a day. He switched his attention to brain activity and eye movements in sleeping adults. At the time most mainstream scientists thought that these eye movements were meaningless events that took place at random times throughout the night. Never one to follow the crowd, Aserinsky dragged an old EEG machine out from the departmental basement to his office and set to work.

He decided to start off by simultaneously measuring people’s brain activity and eye movements throughout an entire night. This ambitious goal pushed the existing technology to its limit, as it required his dated EEG machine to operate smoothly for several hours. Aserinsky decided to carry out an initial test of the equipment by monitoring his son.

So it was that, on a cold night in December 1951, eight-year-old Armond Aserinsky found himself lying in a laboratory bed with his head covered in sensors. Some of the sensors measured his brain activity and others monitored the muscles around his eyes. All of this information was fed back to the EEG machine in a nearby room, where Aserinsky Sr sat watching several pens trace out the activity on a long roll of graph paper. This was no small-scale enterprise, with a single night of monitoring resulting in over half a mile of graph paper. As the night went on, Aserinsky Sr struggled to keep the out-of-date EEG machine up and running, unaware that he was just about to secure his place in history.

A few hours into the session Aserinsky Sr was surprised to see the pens suddenly start to scribble away, indicating that Armond’s brain and eye muscles were highly active. Aserinsky Sr assumed that his son had woken up, and so went along to the corridor to see what had happened. When Aserinsky Sr opened the laboratory door he was amazed to discover that his son was sound asleep. Even more remarkably, this rather curious pattern was not a one-off affair, with Aserinsky Sr observing similar bursts of brain activity and eye movement throughout the night.

The next morning Aserinsky Sr tried to discover the cause of this mysterious activity. At first Aserinsky assumed that the old EEG machine was broken, and started the laborious task of checking the endless leads, dials, and valves. When he failed to find a problem he shared his results with Kleitman. Initially sceptical and perhaps suspecting fraud, Kleitman asked his student to re-run the procedure but this time using Kleitman’s daughter as the participant. When the same pattern of data emerged, Aserinsky became more confident that he was on to something big, and labelled the curious phenomenon ‘rapid eye movement’ or ‘REM’ for short (Aserinsky originally thought about calling it ‘jerky eye movement’ but was worried about the negative connotations of the word ‘jerk’). Intrigued, Aserinsky and Kleitman decided to find out what was going through people’s sleeping minds when the EEG produced these strange nocturnal patterns.

Aserinsky arranged for a group of twenty volunteers to come to the laboratory. He woke them up whenever they entered REM state and interviewed them. Describing his findings in a now-classic paper (‘Regularly Occurring Periods of Eye Motility, and Concomitant Phenomena, During Sleep’), Aserinsky noted that the vast majority of them reported a dream.

This paper had an enormous impact, with one leading scientist announcing that Aserinsky had discovered a new continent in the brain. For years the only dream reports available to researchers had come from people trying to recall their dreams each morning. These reports were often patchy, incomplete, and unreliable. The discovery of REM changed the face of sleep science overnight and provided researchers with a direct route into the dreaming mind. As a result, scientists across the world started to investigate sleep and dreaming. Strangely, Aserinsky was not one of them. Ever the incurably curious polymath, Aserinsky switched to examining the effects of electrical currents on salmon, passing away in 1998 when his car swerved off the road and collided with a tree. Ironically, it is thought that he had probably fallen asleep at the wheel.

Aserinsky's remarkable discovery changed the world, and provided a pathway into the hitherto hidden world of dreaming. It was also the final piece of the sleep-science jigsaw and allowed researchers to map out exactly what happens to people every night of their life. To explore this map, it's time to visit a modern-day sleep centre.

Five amazing facts about dreaming

The discovery of REM has allowed sleep scientists to explore the mysteries of dreaming. Here are five of their strangest findings.

Dreaming in colour

The degree to which people experience colour in their dreams may depend on their childhood experience. Eva Murzyn, from the University of Dundee, asked people in their mid-fifties to rate both the amount of colour in their dreams, and how much black-and-white television they watched during their childhood. 25 per cent of those who only saw monochrome television when they were young dreamt in black and white, compared to just 7 per cent of those who had access to colour television.

Up all night

Researchers have carefully measured the extent of male erections during dreaming and then compared this to the content of the dreams. The findings show that erections happen during even the most mundane of dreams, and are not necessarily the sign of an erotic adventure.

Dreams of the blind

Research into the dreams of blind people has revealed that those who lose their sight before the age of seven experience dreams that contain almost no visual imagery, whereas those who become blind after they are seven years old have the same type of visually oriented dreams as sighted people. Also, those who are blind from birth report dreams that frequently involve vivid sensations of sounds, taste, smell, and touch.

The importance of impotence

Nocturnal erections can help medics to determine the causes of impotence. If a patient does not get an erection during their sleep, then their impotence may be due to a physical problem that is best treated with drugs or surgery. However, if the patient has no problem 'staying up' all night then the problem is likely to be more in the mind.

You are blind when you dream

David Foulkes, from the University of Chicago, invited volunteers to his sleep laboratory, taped open their eyelids, and asked them to fall asleep. When the volunteers started to dream, Foulkes tiptoed into the room and placed various objects in front of their eyes, including an aluminium coffee pot and a card bearing the somewhat ironic message ‘Do Not Disturb’. The volunteers were then woken up, asked to report their dream, and quizzed about what they thought had been happening right in front of their eyes. The volunteers saw nothing, and the objects didn’t crop up in their dreams, suggesting that you become blind when you dream.

A touch of the Bram Stokers

Spend time in any psychology department and you will soon learn to spot the different kinds of researchers at work. The social psychologists are the ones who are unable to maintain eye contact, the memory researchers have forgotten where their offices are, and the persuasion experts will be arguing how best to split a bar tab. No matter how long you spend there, however, you are unlikely to spot that rarest of researchers, the sleep scientist.

This unusual breed enjoys a nocturnal and solitary existence. They arrive at their offices just as everyone else is heading home, climb into their beds when the rest of the world is waking, and often only meet one other person at work (and, all being well, that person will be asleep).

Stevie Williams is one of these researchers. Stevie is the head technician at one of the UK’s best-known sleep clinics – the Edinburgh Sleep Centre. I first met Stevie a few years ago when we were both involved in a project examining whether psychics could dream about the future (they couldn’t). Stevie is in his mid-thirties and, like most sleep researchers, has what I refer to as ‘a touch of the Bram Stokers’. Although healthy looking, his skin has a thin, pallid quality, which I suspect is a direct result of his vampire-like existence.

Stevie had heard about my interest in sleep science, and kindly invited me to spend a night being monitored at his sleep clinic. Entering the clinic’s sleep room is like being on the set of a stage play. On the face of it, everything looks like a normal bedroom or hotel room. Deep down, however, you have a strange feeling that all is not quite as it seems. Sneak a peek behind the bed and you will discover an endless array of sensors, tubes of gel, rubber caps, and miles of cabling. To the twenty-first-century sleep researcher this is exactly what you need to follow people as they journey into the night.

After I had changed into my pyjamas, Stevie glued about twenty small sensors in place on my scalp with a special gel, carefully connected a long wire to each sensor, and then gathered the wires together to form a strange-looking ponytail. The set-up looked bizarre but actually felt surprisingly comfortable. Stevie asked me to climb under the duvet, and then carefully placed the ponytail over the side of the bed. Finally, Stevie checked the positioning of the infrared camera that would record my every toss and turn throughout the night, and left the room.

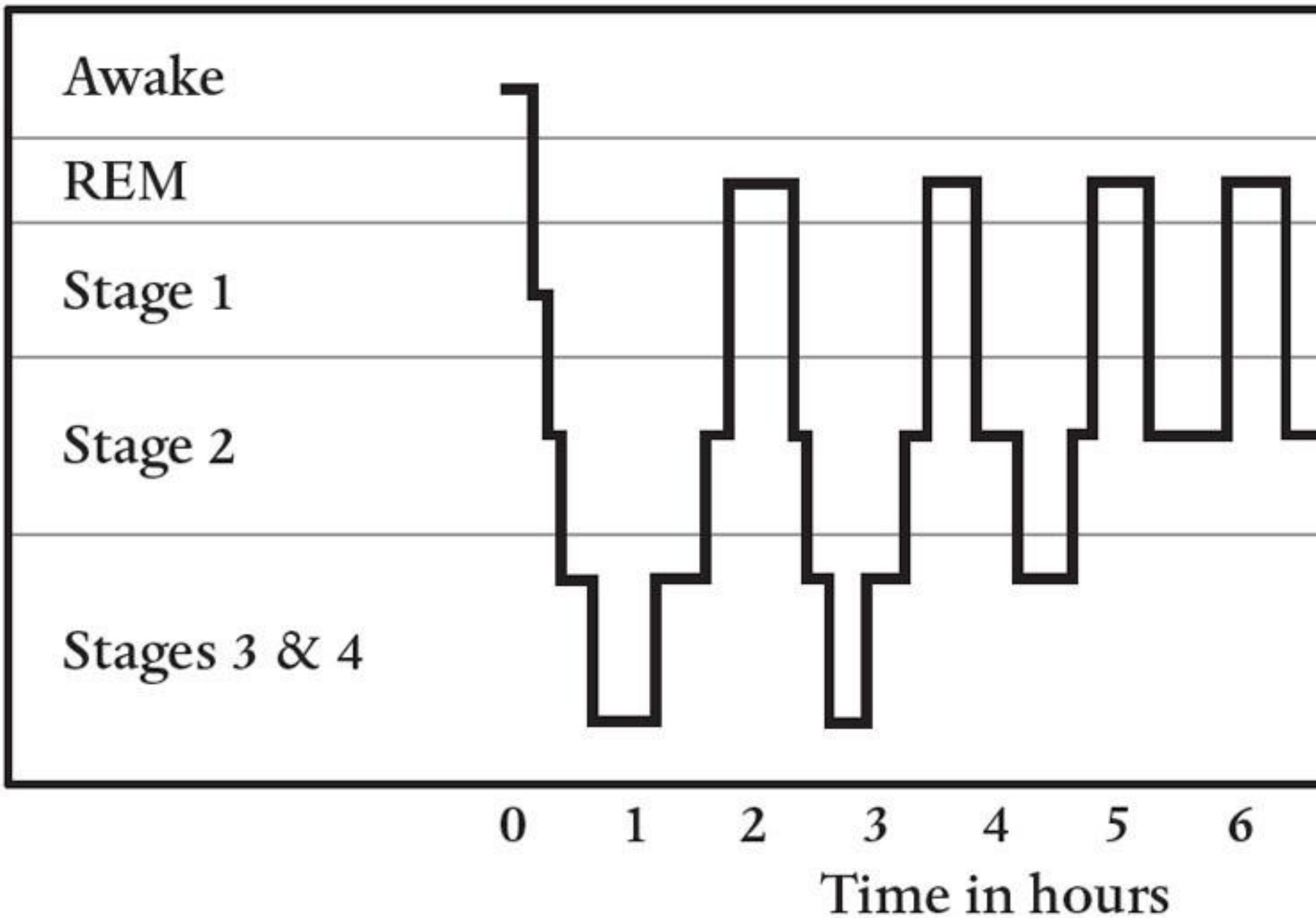
The sleep centre’s bed was remarkably comfortable, and after only a few seconds I found myself drifting off. The next moment Stevie was back by my bed gently waking me up. I assumed that it was the middle of the night and that something had gone wrong with the equipment. In fact, it was 7 a.m., and I had just enjoyed the best night’s sleep that I had had for years. Stevie then asked me to change back into my civvies and meet him in his office.

I felt as if my mind had been in shut down-mode for the previous eight hours. No dreams. No activity. Zilch. Yet when Stevie showed me the EEG graphs from the night it was obvious that nothing could have been further from the truth. As he reviewed my data, it became obvious that my EEG trace was almost identical to the one produced by Aserinsky and Kleitman all those years ago. Modern-day sleep researchers refer to this pattern as the ‘sleep cycle’. Over breakfast, Stevie kindly took me through each stage of the process.

It’s just a stage he’s going through

As we have seen, when you are wide awake your brain produces an erratic-looking EEG trace that contains between twelve and thirty waves each second. Soon after you climb into bed, the frequency of these rapidly changing squiggles slows down until there are only about eight to twelve waves each second. This type of trace is often associated with relaxation and meditation, and is known in the trade as ‘alpha activity’.

After a few more minutes, your breathing will slow down, your eyes will roll from side to side, and the frequency of your brainwaves will become even lower. You are now entering **Stage 1**of sleep (see graph). You only enter this stage a handful of times during the night, and each of these visits is very brief. During this stage your brain will be producing between three and seven waves every second or, to give them their technical name, ‘theta’ waves. If you are woken up during this stage, you are likely to feel like you weren’t really asleep.



During your first encounter with Stage 1 sleep you might produce the odd twitch or two, and see illusory pinpricks of bright light or hear non-existent loud bangs (known as ‘hypnagogic hallucinations’). Your muscles will also start to relax, and you are likely to experience a general ‘loosening’ of thought. Artists and writers have attempted to use this experience as a source of inspiration. For instance, surrealist Salvador Dali would lie down and place a glass on the floor. He would then put one end of a spoon on the edge of the glass and hold the other end between his fingers. As he drifted into Stage 1 of sleep, Dali’s fingers would naturally relax and release the spoon. The sound of the spoon crashing into the glass would then wake him up, and Dali would sketch the odd images that were drifting through his mind.

This stage is also associated with a rather strange phenomenon known as the ‘hypnagogic myoclonic twitch’, which often starts with the sensation that you are falling before you suddenly find that your entire body has jolted itself awake. Around about 70 per cent of people experience these twitches, and they seem to be associated with exhaustion or sleeping in an uncomfortable position. Sleep scientists are not quite sure what causes the twitches, with some researchers arguing that as you fall asleep your muscles begin to relax, and the brain somehow misinterprets this as evidence that you are falling. Some evolutionary psychologists speculate that it might have developed from a time when people fell asleep in trees, and was designed to stop them falling out when they slept like a log.

You only experience Stage 1 of sleep for between two and five minutes. As you drift into the next stage of sleep, your heart rate slows down and your body temperature lowers. The ‘theta waves’ are joined by brief bursts of electrical activity known as ‘spindles’ and ‘k complexes’. These appear to play a vital role in blocking out any external stimuli (such as a noise outside on the street) and internal stimuli (such as feeling a tad peckish) that might otherwise wake you up. You have now reached **Stage 2** of sleep. During this time almost all of your muscles, including those in your throat, start to relax, which can cause you to mumble or snore. Your brain is also taking a well-earned rest too, with a lowering of activity in areas associated with thought, reasoning, language, and problem solving. As we will discover in a later lesson, this stage is vital to learning physical activity, such as mastering a music instrument, new dance, or sporting skill.

Researchers often group the first two stages of sleep together, and refer to them as ‘light sleep’.

After about twenty minutes in Stage 2 of sleep, your brain and body becomes especially relaxed, and you enter **Stage 3** and **Stage 4**. At this point your brain activity is at a minimum, resulting in very slow-moving ‘delta waves’ (only about one or two waves each second). Together, these stages are referred to as ‘deep sleep’ or ‘slow-wave sleep’. During this time you will be almost completely cut off from the outside world (unless you happen to smell burning, someone says your name, or you hear a very loud noise). It’s extremely difficult to wake up someone when they are in deep sleep, and if you do manage it they are likely to feel groggy and disoriented for several minutes.

Deep sleep stages are vital to your psychological and physical well-being because they are associated with the production of growth hormones that help repair damaged tissue. Without these stages you would wake up feeling tired and grumpy. These stages are also important for consolidating important information from the day, and are also associated with sleepwalking, sleep talking, and night terrors. When Stevie looked at my EEG trace he could see evidence of my tendency for night terrors. During deep sleep it’s unusual for people to move around, but the recording from the infrared camera showed that I often moved my hands and arms.

Sleep scientists classify the first four stages of sleep as ‘Non-REM’ (or ‘NREM’) because they don’t involve the type of rapid eye movements associated with dreaming. But does this mean that there is nothing going through your head during this time? If you are woken up from NREM sleep you are highly likely to report some kind of random, fragmented thought. This might take the form of a single word, or concept, and lack the strong sense of storyline that we commonly associate with dreaming.

After around thirty minutes in deep sleep, something very strange happens. Your brain and body move rapidly back through the different stages until you reach Stage 2. Then, instead of being relaxed, your heart starts to race, your breathing becomes shallow, and your eyes dart from side to side. Now you are experiencing rapid eye movement, or **REM**. During this time your brainstem completely blocks any bodily movement to prevent you acting out your dreams. If you were to be woken up now you would almost certainly describe a vivid dream. It is also quite likely that your sexual organs will be going into overdrive, with men gaining an erection and women showing increased blood flow to the vagina. Most people are in REM state, on and off, for about a quarter of the night, and this is sometimes referred to as 'paradoxical sleep' because the brain is almost as active as it is when you are awake. As we will find out later on in *Night School*, this stage plays a vital role in enhancing your memory, helping you deal with traumatic events, and seeing problems from a fresh perspective.

Having completed your first dream of the evening you move back down through the stages, and this NREM–REM–NREM sequence repeats itself again and again throughout the night. Each cycle takes around ninety minutes, resulting in an average of five dreams per night.

After each dream you might experience a very brief 'micro-awakening', wherein you are actually fully awake but for such a short time that you will not remember it in the morning. In a typical night, about 50 per cent of the time is spent in light sleep, 20 per cent in deep sleep, 25 per cent in REM, and 5 per cent having brief awakenings. The start of the night tends to be dominated by deep sleep, with relatively short dreams. However, as the night wears on the dreams become progressively longer and the periods of deep sleep correspondingly shorter. Indeed, in the second half of the night there is almost no deep sleep, and the REM can last up to forty minutes at a time.

The ninety-minute rule

Speak to sleep researchers and you will soon discover that most of them use a little-known trick to help them feel refreshed the next day. You will feel most refreshed when you awake at the end of a ninety-minute sleep cycle because you will be closest to your normal waking state. To maximize the chances of this happening, figure out when you want to wake up, then count back in ninety-minute blocks to find a time near to when you want to go to sleep.

Let's imagine that you want to wake at 8 a.m., and wish to go to sleep around midnight. Chunking back in ninety-minute segments from 8 a.m. would look like this:

8 a.m. → 6.30 → 5.00 → 3.30 → 2.00 → 12.30 → 11 p.m.

In this example, you should fall asleep around either 11 p.m. or 12.30 a.m. in order to feel especially refreshed in the morning.

After breakfast I thanked Stevie for talking me through the night, said goodbye, and walked out into the morning sun ready to face the day. Behind me, Stevie locked up the sleep laboratory and headed for his bed.

The sleep cycle plays a vital role in understanding what happens to your brain and body every night of your life. It is, however, only part of the picture. To fully appreciate the fundamental nature of sleep it's also important to get your head around a second key idea. It's time to discover what really makes you tick, and meet a man who changed the world by locking some plants in a cupboard.

The clockwork universe

The great eighteenth-century French astronomer Jean-Jacques d'Ortous de Mairan spent much of his career staring up at the sky. In 1729, however, a rather more down-to-earth phenomenon caught de Mairan's attention. For centuries philosophers had observed plants opening their leaves during the daytime and closing them at night, and concluded that this curious behaviour was driven by sunlight. De Mairan wasn't convinced by their arguments, and decided to conduct a simple study that would put centuries of accepted wisdom to the test.

De Mairan decided to conduct his now-classic experiment with the help of the *Mimosa pudica*, a plant known for its rapid and highly predictable leaf movements. Each morning the *Mimosa pudica* opens and lifts its leaves, and every evening it closes and lowers them. De Mairan reasoned that if the *Mimosa pudica* were influenced by sunlight then it should stop moving when it is placed in total darkness. To find out if this was the case, he took one of the plants and locked it away in a pitch-black cupboard. Throughout the following few days de Mairan carefully lit a candle and peaked inside. Despite having no access to sunlight, the plant's leaves remained perky during the day and flaccid at night. His study had revealed that many of the world's greatest philosophers had made a terrible error, and that sunlight was not responsible for the *Mimosa pudica*'s behaviour.

At the time of his discovery de Mairan was working on several important astronomical projects, including exploring whether the colours of a rainbow were related to musical scales and trying to observe Venus's non-existent moons. As a result, the astronomer wasn't especially interested in publishing his work with the humble *Mimosa pudica*. In fact, the paper might not have seen the light of day, had it not been for his friend and fellow scientist, Jean Marchant. Marchant was convinced that de Mairan had made a major breakthrough, and insisted that the paper was published in the proceedings of the Royal Academy of Paris. The article consisted of just 350 words. Nevertheless, it changed the science of sleep forever.

Over the next 200 years scientists carried out ever more complex versions of de Mairan's study in an attempt to discover the strange force controlling the opening and closing of plants. After locking away thousands of plants in ever more secure cupboards, they ruled out every possible candidate, including temperature, humidity, and the earth's magnetic field. Eventually the researchers realized that plants were not responding to an outside force at all, but instead possessed a mysterious kind of internal clock that merrily ticked away regardless of what was happening in the world. Like a beautifully crafted timepiece, this internal clock worked on a twenty-four-hour cycle and ensured that the plant’s leaves opened during the day and closed at night.

Flushed with success, the scientists then started to search for similar internal clocks hiding away in other forms of life. From the simplest single-celled organisms to the most amazing mammals, time and again they found what they were looking for. It soon seemed as if the whole of the natural world was controlled by clockwork. After decades of hard work the researchers finally reached the last item on their list: Homo sapiens.

Everyone has a natural tendency to wake up each morning and go to sleep every night, and researchers wondered whether this behaviour could also be the result of an internal clock ticking away in their brains and bodies. It was time for an experiment. De Mairan’s initial groundbreaking study involved placing plants inside a pitch-black cupboard and then regularly observing their behaviour. Although carrying out the same study with humans might be fun (providing you weren’t the ones in the cupboard), it wouldn’t rule out other environmental factors that could influence the wake–sleep cycle, such as temperature, sound, and humidity. To stage de Mairan’s experiment with humans, researchers needed to find a location that was completely isolated from the outside world and someone who was willing to stay there for a long time. Enter Michel Siffre, French scientist and adventurer extraordinaire.

Going underground

Born in 1939, Michel Siffre developed a passion for caving and science at an early age. After graduating with a degree in speleology (the study of caves) in his early twenties, Siffre was on the hunt for an interesting research project. At the time a team of geologists had just discovered a subterranean glacier deep inside the French–Italian Alps, and Siffre realized that this was the perfect location for a groundbreaking experiment into the possible existence of the human internal clock.

In 1962, the twenty-three-year-old French adventurer descended nearly 400 feet below the earth’s surface and lived in the cave for two months. Throughout the ordeal Siffre regularly telephoned his above-ground team to tell them when he had just woken up or was about to fall asleep. The experiment wasn’t easy. Enduring below-freezing temperatures and very high humidity, Siffre suffered from hypothermia and frequently had to dodge large chunks of ice that fell around his tent. Yet Siffre’s daily diary shows that he only lost the plot on one occasion. Tired, lonely, and clad only in a pair of black silk stockings, he decided to sing loudly while twisting the night away.

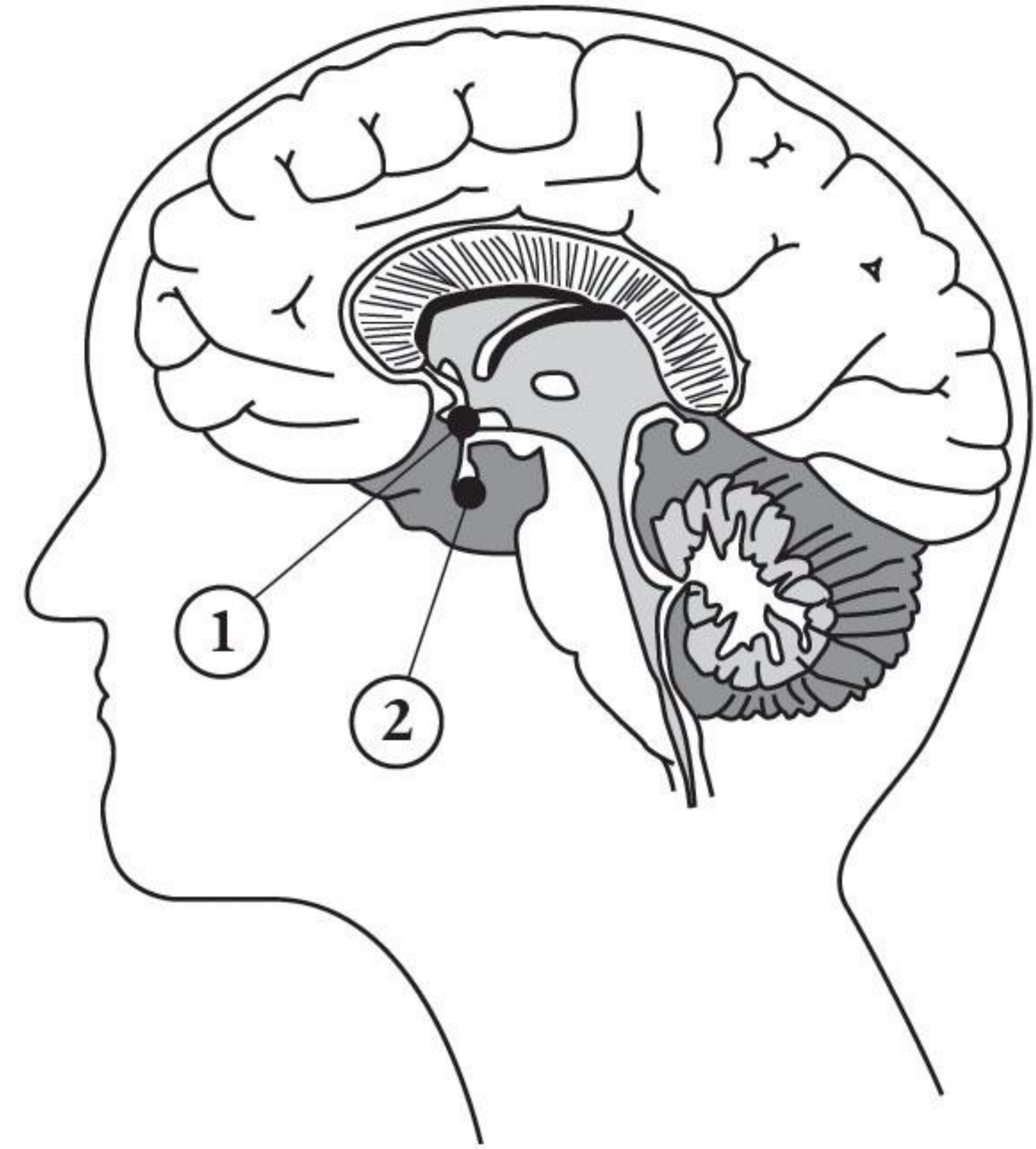
Siffre’s suffering paid off, and the results revealed that humans do indeed have an internal clock ticking away inside them. In the same way that the plants in de Mairan’s experiment regularly opened and closed their leaves despite being deprived of sunlight, Siffre continued to go to bed and wake up roughly every twenty-four hours. Over the next few years other sleep researchers investigated this mysterious internal clock by locking themselves and others in increasingly isolated underground locations. Their results have revealed an extraordinary insight into what really makes you tick.

The rhythm of life

Earlier in this lesson we discovered that your brain is made up of billions of neurons. Now let’s take a somewhat bigger perspective and examine how large clusters of these neurons affect how you think and feel. If we removed your brain from your skull, and sliced it vertically in half, you would see something that resembled the following diagram (albeit without the labels).

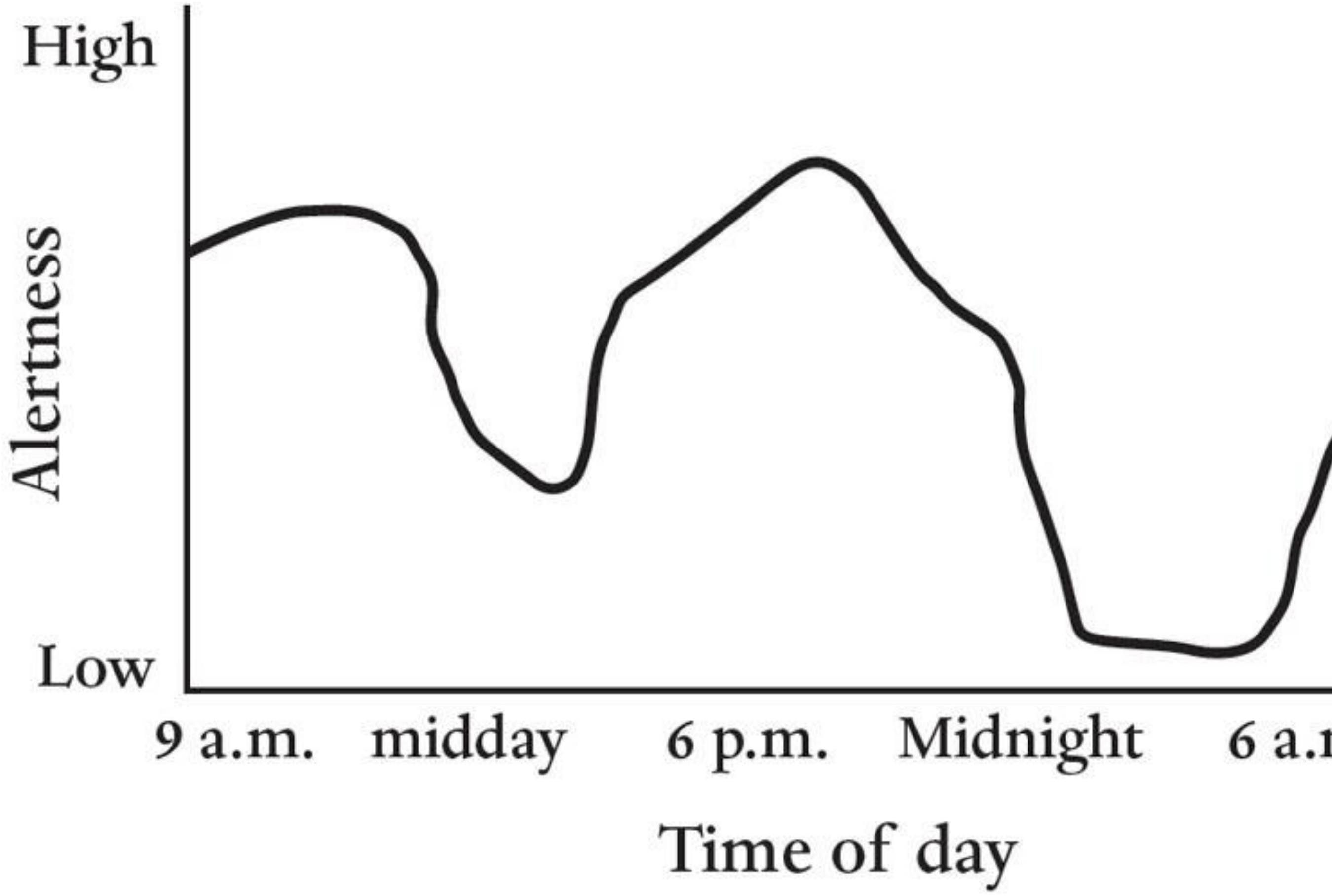
Let’s take a very quick look at some of the main parts of your brain. Towards the front there are the appropriately named ‘frontal lobes’ that are responsible for lots of things, including your level of self-control and ability to plan. In the middle there is the ‘amygdala’, which plays a key role in controlling your emotions, while at the back is the ‘occipital lobe’, which analyses the information from your eyes, and allows you to see the world. There, that didn’t take long did it? Oh, hold on, I missed out two important parts.

First, take a look at the tiny black dot towards the middle left of the diagram (1). That is your ‘suprachiasmatic nucleus’. This pinhead-sized group of about 10,000 neurons acts as your internal clock and merrily tick-tocks away every moment of your life.



Second, the other black dot towards the middle right of the diagram (2) is your ‘pineal gland’. This pine-cone-shaped structure (thus the term ‘pineal’) is only about the size of a grain of rice but, nevertheless, has long fascinated philosophers, neuroscientists, and hippies. The famous seventeenth-century French philosopher René Descartes spent much of his life investigating the pineal gland, and eventually declared that it was the ‘principal seat of the soul’. More recently New Agers have claimed that the area acts as a magical inner eye and is part of a holistic chakra system that promotes mystical awakening and ancient enlightenment (or something like that). But Descartes and the New Agers are wrong. In fact, the pineal gland is responsible for something far more important. At certain times of the day the suprachiasmatic nucleus causes the pineal gland to produce a sleep-inducing hormone called ‘melatonin’, making you feel drowsy and tired. Your internal clock sends these signals as part of a highly predictable pattern that repeats itself every twenty-four hours. Sleep scientists refer to this pattern as a ‘circadian rhythm’, a term derived from the Latin word *circa*, meaning ‘around’, and *dies*, meaning ‘a day’. Let’s take a quick look at this pattern in more detail.

As with any cycle, you can begin to examine the effects of your internal clock at any point in the day. Let’s start at 6 a.m. At this godforsaken hour most people feel pretty sleepy. However, for the next five hours your internal clock will make you feel steadily more alert, explaining why most people wake up between 7 a.m. and 9 a.m., and feel pretty good during the first few hours of the day. Starting at around about 11 a.m., you will slowly become less and less alert, leading to an all-time daytime low at about 3 p.m. If you are able to nap, this is the perfect time to nod off. However, do make the most of your nap time because this dip will only last for about an hour or so, and from about 4 p.m. onwards you start to become ever more energetic and perky, peaking at about 8 p.m. Then, from about 9 p.m. onwards, you experience a slow decline in energy levels, which encourages you to fall asleep just before midnight. Finally, these low levels continue throughout the night, and at 6 a.m. the following morning the entire process starts to repeat. And so the pattern continues throughout every day of your life. Like the gentle ebb and flow of the tide, your level of alertness gently rises and falls throughout the day.



Years of research have provided several important insights into this process.

There has been, for instance, work examining sleep and babies. We are not born with Circadian Rhythms 1.0 pre-installed. Instead, newborns take lots of randomly timed naps throughout the night and day, resulting in them sleeping for about sixteen hours a day, and the rest of the time making as much noise as possible. As you might imagine, this is a joy to be around. However, the good news is that their circadian rhythms develop quite quickly, and within about six months they sleep more during the night-time.

Circadian rhythms undergo a major shift during our teenage years. Contrary to popular belief, teenagers that appear to be super-glued to their beds are not simply being lazy. During adolescence, circadian rhythms often shift by about three hours, resulting in teenagers not feeling sleepy until very late at night and not being able to prise themselves out of bed until late morning.

However, perhaps the most frequently researched aspect of the topic has examined the variation between the timing of people’s circadian rhythms. Sleep scientists refer to this as your ‘chronotype’, with everyone falling on a continuum between those that naturally want to head to bed late at night and get up in the middle of the day (extreme ‘owls’), and those that fall asleep early in the evening and spring out of bed at the crack of dawn (extreme ‘larks’). Over the years researchers have developed various ways of measuring people’s owl–lark tendencies, including monitoring their body temperature and levels of the naturally produced hormone melatonin in their blood. One of the most widely used ways of classifying people involves asking them to complete a questionnaire about their preferred bedtime, how they feel in the morning, and whether their heads rotate through 360 degrees. I asked you to complete one of these questionnaires just before the start of this lesson (). Take a look at your answers now.

To score the questionnaire, add up the numbers (shown in italics) associated with each of your answers, and then use the following scale to discover where you fall on the lark–owl continuum.

4–6	**7–10**	**11–13**	**14–17**	**18–20**
Strong lark	Moderate lark	Neither owl nor lark	Moderate owl	Strong owl

Your chronotype is primarily determined by your genes, and so tends to run in families. It also has a large impact on the way that you think and behave. Perhaps not surprisingly, when it to comes to sleep, extreme larks like to be in bed by 10 p.m., wake up around 6 a.m., rarely need an alarm clock, and don't tend to nap during the day. In contrast, extreme owls like to go to sleep around 1 a.m., rise about 9 a.m., often set several alarms, and enjoy daytime napping.

In terms of when you do your best work and feel good, larks are most alert around noon and feel happiest between 9 a.m. and 4 p.m., whereas owls are most productive around 6 p.m. and feel at their best between 1 p.m. to 10 p.m.

There is a great deal of debate around the relationship between people's chronotype and their personality, but in general larks tend to be introverted, logical, and reliable, whereas owls are more extroverted, emotionally stable, hedonistic, and creative. On the downside, owls are also more likely to be untrustworthy, psychopathic, and narcissistic. Perhaps not surprisingly, these differences have a dramatic effect on people's personal lives with, for example, research showing that, on average, owls have four times as many partners as larks during their lifetime. People's chronotype also affects their relationship with food, with larks showing a strong tendency for eating breakfast within thirty minutes of waking and owls being much more partial to a midnight feast. Unfortunately, lots of large evening meals tend to take their toll over time, causing more owls than larks to suffer from obesity.

There is also a strong relationship between chronotype and academic performance, with larks getting higher grades than owls. Researchers originally thought that this was due to larks being more intelligent than owls. In fact, the early start times adopted by most schools means that owls are often studying, and being examined, when they are not feeling at their best.Because of this, several education experts think that there is a strong case for measuring pupils' chronotypes, and then using this information to help maximize their performance by, for example, scheduling lessons and exams at more appropriate times of the day.

School children and students are not the only ones to suffer because of their chronotype. Chronobiologist Till Roenneberg, from the Ludwig Maximilian University of Munich, has argued that adults' internal clocks are also frequently out of step with their surroundings.During the week, many office workers are expected to be at their desks by 9 a.m. This is fine for larks, but tricky for owls. Struggling to go to bed earlier in the night, those with owl-like tendencies often only get a few hours' sleep before having to get up for work. As a result, they spend much of the week feeling overly tired, and so have to try to catch up on their lost sleep during weekends. For larks, it's the weekends that cause the problem. Many people's social lives involve staying up late on Friday and Saturday nights. Even if larks do manage to keep their eyes open at this time, they often struggle to lie in the following day and so end up getting very little sleep. Roenneberg has argued that both phenomena result in a kind of 'social jet lag' that is leaving large numbers of people constantly feeling tired.

However, perhaps the most important work into our internal clocks has examined how they can be used to help treat those struggling to sleep.

Rhythm and blues

Like many timepieces, your internal clock is not entirely accurate. In fact, Siffre's study showed that your internal clock is probably slightly on the slow side, taking just over twenty-four hours to complete a single cycle. Left unchecked, this small difference would cause you to slowly drift out of sync with the actual time, and after just a few weeks you would feel sleepy at the start of the day and wide awake when darkness fell. To help prevent this happening your internal clock is re-set each day by several factors, such as when you eat, move around and, most important of all, the amount of light entering your eyes.

The light swirling around you right now not only allows you to read these words (and, for that matter, these ones too), but also has a dramatic effect on your brain. This light is entering your eyes and causing your retinas to produce tiny electrical signals that are then stimulating your suprachiasmatic nucleus and pineal gland. When these brain structures receive this stimulation they stop producing the sleep-inducing hormone melatonin, and so you feel alert and awake. However, if you were to turn out all the lights, your retinas would cease to stimulate these bits of your brain, and the subsequent release of melatonin would make you feel drowsy and tired. For this reason neuroscientists often refer to melatonin as the 'Dracula hormone' because it only emerges in the dark.

Unfortunately, some people's clocks fail to respond to these light cues, causing them to suffer from what is referred to as a 'circadian timing disorder'. Over time, those suffering from the disorder slowly drift out of sync with actual time, eventually either going to bed very late at night ('delayed sleep phase disorder') or extremely early in the evening ('advanced sleep phase disorder'). Unlike most people with insomnia, sufferers tend to enjoy several hours of uninterrupted sleep. However, on the downside they find themselves getting up very late in the morning or towards the middle of the night, which can become problematic if their jobs or social lives require them to keep normal hours. Treatments often involve people sitting in front of commercially available 'light boxes' that expose them to massive amounts of illumination in attempt to re-set their internal clocks, with those suffering from delayed sleep phase disorder seeing the light between 7 a.m. and 9 a.m., and those experiencing advanced sleep phase disorder doing the same between 7 p.m. and 9 p.m.

Research into circadian rhythms has also discovered what to do when our internal clock fails to tell the right time. If you jet around the world, you cross one or more time zones, and your internal clock is unable to keep up with the change. As a result, you soon start to experience an annoying phenomenon known as 'circadian dysrhythmia' or, as most people refer to it, 'jet lag'.

Let’s imagine, for example, that you are going to take a six-hour flight from London to New York, and that you will leave London at noon. When you arrive in New York your internal clock will think that it is 6 p.m., and so you might feel a tad tired and ready for an evening meal. Unfortunately, the actual time in America will be 1 p.m. and everyone there will be all alert and tucking into their lunch. As a result you will be suffering from an east-to-west lag that sleep researchers refer to as ‘phase delay’. Now let’s imagine that you had instead flown from New York to London, leaving New York at noon. In this scenario you would arrive in London thinking it is 6 p.m., and ready to head out on the town for a bite to eat. Unfortunately, the actual time in London will be 11 p.m. at night and so most people there will be heading to their beds. As a result, you will suffer from a west-to-east lag called ‘phase advance’.

Over time, the light levels at your new destination will slowly re-set your internal clock to the correct time. However, before then, life can be tricky, with people feeling overly tired, thick headed, and ill. Phase delay is far less disruptive than phase advance, and so flying east to west usually creates far fewer problems than flying west to east, but even relatively small differences can have a surprisingly large effect on the brain and body. In one set of intriguing studies, Lawrence Recht from the University of Massachusetts and his colleagues examined the performance of North American major league baseball teams. When a team had to fly east to west before a game they won 44 per cent of the time. In contrast, when they had to travel west to east they were victorious just 37 per cent of the time.

Jet lag is unlikely to be a problem if the time difference between your point of departure and destination is less than three hours. Similarly, if you are only going to be away for a couple of days or less, it might be easiest to stay on your ‘home time’. For all other long-haul trips, the difference between your internal clock and the actual time may well cause you to feel disoriented, light-headed, and listless. Adjusting to a new local time takes about half a day per time zone if you are flying east to west, and two-thirds of a day per time zone if you are flying west to east. However, worry not, because help is hand, with researchers developing several methods for beating jet lag (see box).

Top tips to help overcome jet lag

- Make good use of the days before you fly by starting to shift your body clock to the time at your destination. If you are flying to the east, get up slightly earlier. If you are flying to the west, get up slightly later.

- If possible, book flights that will minimize jet lag by following the simple adage, ‘Fly east, fly early. Fly west, fly late.’

- If you need to sleep during the trip, try to avoid sitting on the sunny side of the plane. For flights in the northern hemisphere, the sun will tend to be on the left side of the plane when you fly west, and on the right side when you go east. Several websites offer more precise guidance for specific flights.

- As soon as you board the plane, adjust your watch to show the time at your destination, and try to fit into this new time schedule as soon as possible. If it is time to sleep, get your head down. If it is dinner time, eat something.

- Some people believe that melatonin supplements can help control your sleeping patterns and thus help you adjust to new time zones. Research suggests that daily doses of melatonin can help alleviate jet lag, and that short-term usage seems to have few negative side effects. Consult your doctor before taking any medication.

- When you arrive at your destination, adjust your circadian rhythm by using the following simple rules of thumb:

— If you have travelled east, avoid the morning sun and seek out natural light in the afternoon.

— If you have travelled west, seek out light throughout the entire day.

- If you really cannot keep your eyes open during the day, take a quick nap, but set your alarm to make sure that it is no longer than two hours.

In this lesson we have explored two concepts that play a fundamental role in sleep. First, we discovered what happens to you every night of your life, and unlocked the mysteries of light sleep, deep sleep, and REM. In the second part of the lesson we turned our attention to circadian rhythms, examining how they determine where you sit on the lark–owl continuum, cause teenagers to struggle to climb out of bed in the morning, and can be used to overcome jet lag. Having dealt with these two fundamental concepts, in the next lesson we will turn our attention to what happens if you don’t spend enough time in bed.