- Brain

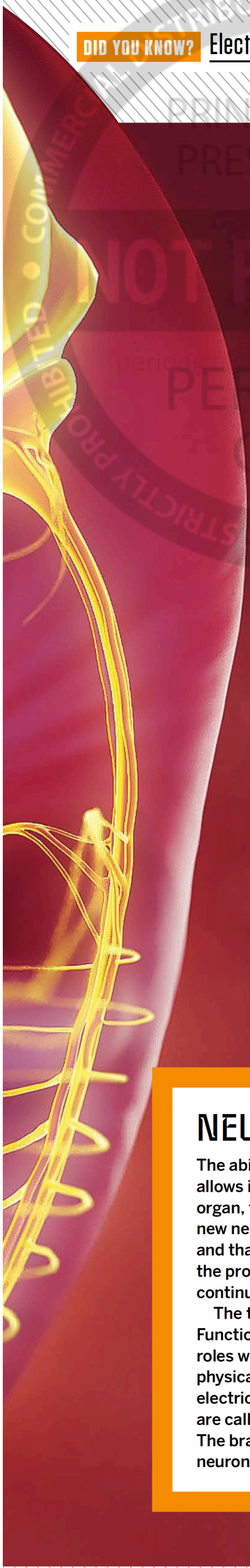
SCIENCE

# HOW OUR BRAINS DEVELOP

**Why the way you think changes as your brain grows**

WORDS AILSA HARVEY

**DID YOU KNOW?** Electric impulses in the brain can travel at 350 miles per hour



The brain is the most complex organ in the human body, so it makes sense that it doesn't develop overnight. In fact, to reach its full functionality, it takes most of the first three decades of your life. You use your brain to conjure up every conscious and unconscious thought, automatically control physiological actions like breathing, experience emotions and comprehend sensations. Naturally, everything in the body requires the brain – it produces your personality and is the central computer of your being. The organ itself comprises 60 per cent fat and 40 per cent water, proteins, carbohydrates and salts. The contents are split into white matter and grey matter. White matter is the deeper portion of the brain, containing nerve fibres covered in a protective membrane coating called myelin. Meanwhile, the grey matter is where information is processed, as this contains the central parts of brain cells, called neurons.

Most everyday actions feel automatic to most people. If you need to collect something from the other side of the room, you might walk over and pick it up with minimal effort. However, life doesn't begin like this. Although the brain is formed before birth, ready to navigate life in the world, it lacks the capacity to engage in many simple physical and mental processes. Over the years, pathways in the brain that carry electrical signals become strengthened. Motor pathways, which exist at the front of the brain in a region called the motor cortex, need to be engaged in order to plan, execute and control voluntary physical movements. When a baby attempts to walk, it perfects the action through trial and error.

The brain uses sensory input to navigate, balance, reposition foot positions and change posture. Different regions of the brain are responsible for different movements, so as neuron pathways are built and strengthened in the brain, the movements available to a person increase. Environmental factors also influence this. Supportive parents and caregivers who encourage their babies to practise moving and walking, or provide words of praise when they take a step, speed up the development of motor skills. Every time an action is practised, more pathways are created in the brain, and the stronger they become.

Your ability to strengthen the brain doesn't stop when you've learned the basics. Every time you train your brain – whether that's taking up a new skill or testing its ability to perform existing skills – the brain's reactive ability and the strength of connections are built. Playing a musical instrument increases grey matter in areas of the brain responsible for motor skills and hearing, for example. Your brain is extremely malleable, continuously shaping itself with new skills, or removing traumatic or useless information. How we treat our brain impacts how its power develops as we interact with the world.

**Did you know?** The brain is the fattiest organ

## NEUROPLASTICITY

The ability of the brain to change and evolve is called neuroplasticity. This allows it to reorganise neural pathways and create new neurons to grow the organ, form new memories and build intelligence. It was once thought that new neurons were only produced during the early formation of the brain, and that shortly after birth this stopped. However, now scientists know that the production of neurons, called neurogenesis, gradually declines but continues throughout life.

The two types of neuroplasticity are functional and structural plasticity. Functional plasticity is the ability to utilise other areas of the brain for different roles when parts are damaged. Structural plasticity is how the brain changes physically as you learn new things. Neurons have gaps between them for electrical impulses to relay signals and information throughout the brain. These are called synapses, and when you're born you have around 2,500 per neuron. The brain grows rapidly to increase the number of synapses to 15,000 per neuron by the time you're three years old.


A child can pick up a new language quicker than an adult due to greater neuroplasticity

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# KEY REGIONS

What traits are associated with the development of each section of the brain?

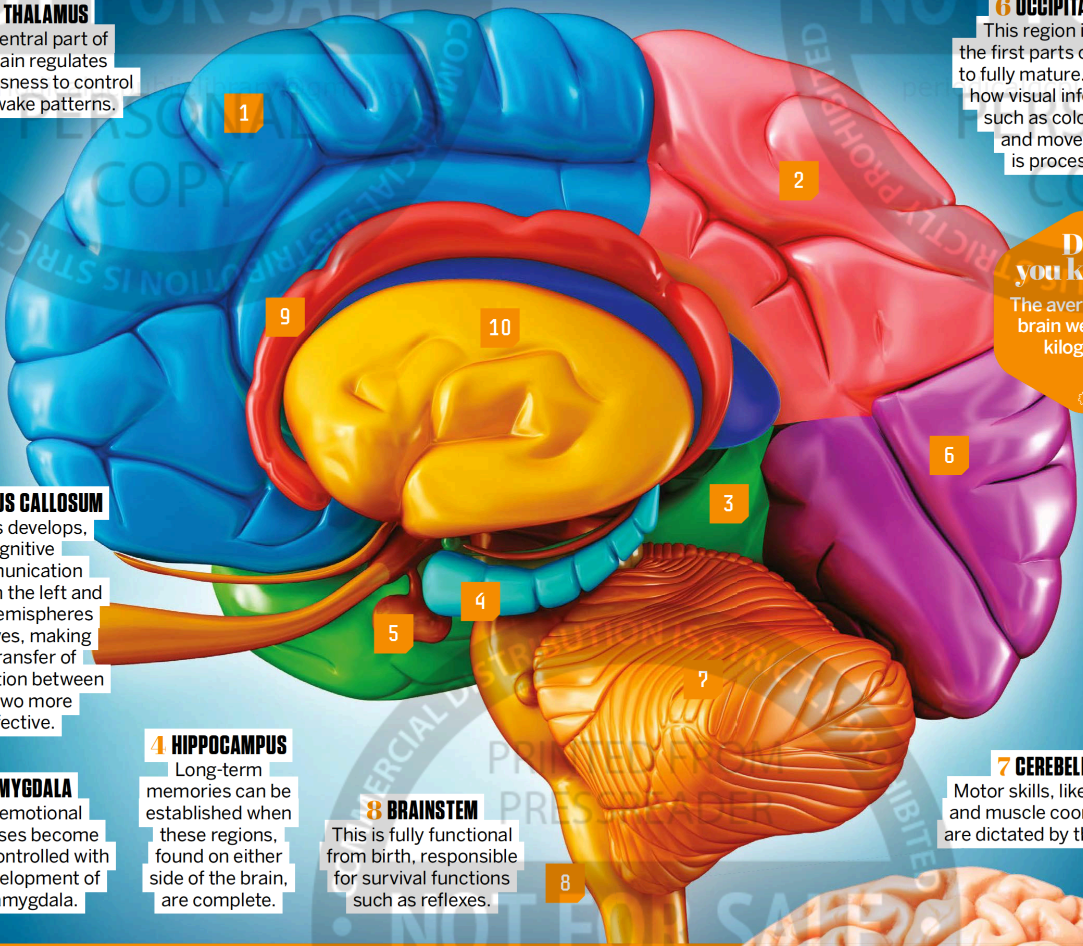
**1 FRONTAL LOBE**
This is the last part of the brain to mature. It's responsible for controlling an individual's personality and understanding of social norms.

**2 PARIETAL LOBE**
The development of this region helps a person interpret sensory information and understand their body.

**3 TEMPORAL LOBE**
When this fully develops, you can effectively process sounds and comprehend language.

**10 THALAMUS**
This central part of the brain regulates consciousness to control sleep-wake patterns.

**6 OCCIPITAL LOBE**
This region is one of the first parts of the brain to fully mature. It controls how visual information, such as colour, light and movement, is processed.




**Did you know?**
The average adult brain weighs 1.4 kilograms

**9 CORPUS CALLOSUM**
As this develops, cognitive communication between the left and right hemispheres improves, making the transfer of information between the two more effective.

**5 AMYGDALA**
Your emotional responses become better controlled with the development of the amygdala.

**4 HIPPOCAMPUS**
Long-term memories can be established when these regions, found on either side of the brain, are complete.

**8 BRAINSTEM**
This is fully functional from birth, responsible for survival functions such as reflexes.

**7 CEREBELLUM**
Motor skills, like balance and muscle coordination, are dictated by this region.

## BUILDING AN INTELLIGENT BRAIN

What makes a brain smart? Intelligence is one of the most useful traits in humans. It can help you achieve your goals, apply logic and reason, adapt to new situations and ultimately survive. For these reasons, neuroscientists have studied the structure and activity in intelligent brains in much detail. Some studies have shown that the brains of more intelligent people are wired differently in how regions interact with each other. For example, the anterior insula and anterior cingulate cortex have stronger connections with the rest of the brain. The anterior cingulate cortex works to maintain concentration and decision-making, while the anterior insula controls decision-making and interpreting social cues. Together, they interact with the learning and memory regions of the brain. In addition, research has shown that by the age of 42, a thicker cerebral cortex correlates with higher intelligence. The cerebral cortex is the outer layer of the brain's surface. In children around ten years old, however, it's the surface area of the cerebral cortex that influences intelligence.

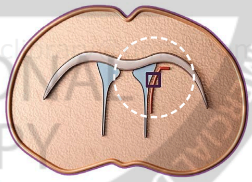
The brain's cerebral cortex contains wrinkles and folds, maximising its surface-to-volume ratio

**DID YOU KNOW?** A piece of brain tissue the size of a grain of sand contains 100,000 neurons


Neurons fire up when they're activated

# HOW NEW CELLS ARE MADE

Neurogenesis is a process that takes place along the walls of the subventricular zone, spanning across the central part of the frontal, parietal, temporal and occipital lobes



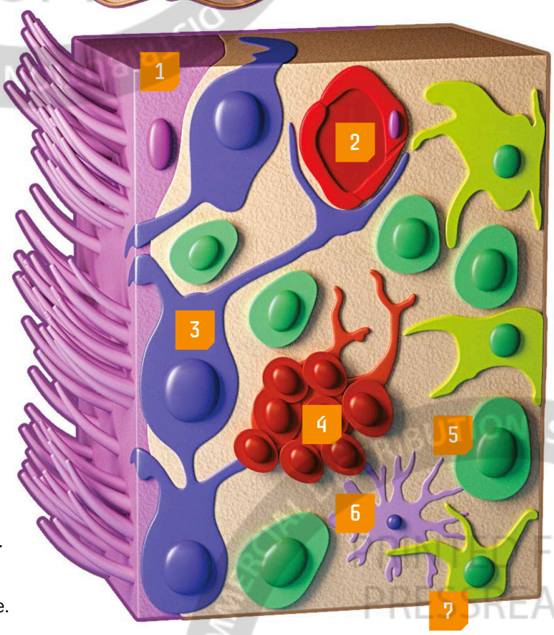
**1 EPENDYMAL CELL**
Lining the brain's ventricles, these support stem cells as a barrier to control the surrounding fluids.

**2 BLOOD VESSEL**
Blood carries oxygen and nutrients towards the cells and waste products away from them.

**3 NEURAL STEM CELL**
These have the ability to change into any specific type of brain cell needed.

**6 MICROGLIAL CELL**
These support cells patrol the brain in search of damaged or dead cells. Microglial cells eat damaged cells to maintain brain health and can recycle any useful nutrients.

**7 INTERMEDIATE PROGENITOR CELL**
IPCs are in the first stage of differentiation. They haven't fully matured, but have committed to a cell type.




**4 NEUROBLAST**
Neuroblasts are cells that have begun to develop into fully functional neurons. They migrate through the brain until they mature into part of the brain's circuit.

**5 TRANSIENT AMPLIFYING CELL**
These are released by stem cells. They play the same role as neural stem cells, but can divide more rapidly to become mature cells.

## STARTING TO SHRINK

**As with the rest of the body, the brain begins the ageing process upon reaching adulthood. When you reach your 30s and 40s, the brain starts to decrease in volume. The frontal lobe and hippocampus shrink at a faster rate than other regions of the brain. The shrinking of the frontal lobe affects memory, emotions and impulse control in older age, while the change in hippocampus size hinders motivation and learning regulation. Other natural changes in the brain in later life include the thinning of the outer surface, reduction in nerve fibres that transmit signals between brain cells and changes in chemical production that keep the brain functioning optimally. Despite the fact that you naturally lose brain cells throughout adulthood, this is a very gradual process for most. When some regions lose mass, others can adapt and take on new roles to maintain efficiency.**


After 40 years of age, the brain starts to shrink about five per cent each decade

## 5 FACTS
### MALE VERSUS FEMALE

**1 BRAIN PROPORTIONS**
A male brain generally has a larger inferior parietal lobule – part of the brain linked with time and speed estimation. A female has larger areas of the brain responsible for language.

**2 WHITE:GREY**
Female brains have ten times more white matter than male brains, but a male's brain has 6.5 times more grey matter. White matter is essential for communication and grey for information processing.

**3 CONNECTIVITY**
A male brain has better communication within the hemispheres, while a female brain has better connectivity between the two.

**4 CHEMISTRY**
Some hormones and neurochemicals in the brains of males and females are processed differently. The mood-stabilising chemical compound serotonin has a 52 per cent higher production rate in male brains.

**5 MEMORY STORAGE**
Parts of the brain relating to memory storage are larger in female brains. This makes women more likely to remember accurate details of events that occurred a week ago.

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# CONCEPTION TO FULL COGNITION

Your brain is constantly evolving, reaching full maturity at around 25 to 30 years old

A baby's brain is highly receptive to sensory input

This microscope image shows myelinated nerves

**Did you know?** A three year old's brain is twice as active as an adult's

## 1 EARLY DAYS

The brain's early structure, the neural tube, forms in the womb. At 35 days, the structure has fused to form a tube. The foetus is six to seven millimetres in length and the early structures of the brain and spinal cord are visible. The brain can already process sensory information like sound, touch and light.

## 2 TAKING SHAPE

The forebrain, midbrain and hindbrain form into three distinct structures. Neurons form at a rapid rate of 15 million per hour, building structure and activity within the brain. As the newly made neurons migrate to different parts of the brain, the foundations of complex neural pathways are established.

The brain is 25 per cent of its adult size when a baby is born. It has 100 billion neurons and 50 trillion synapses.

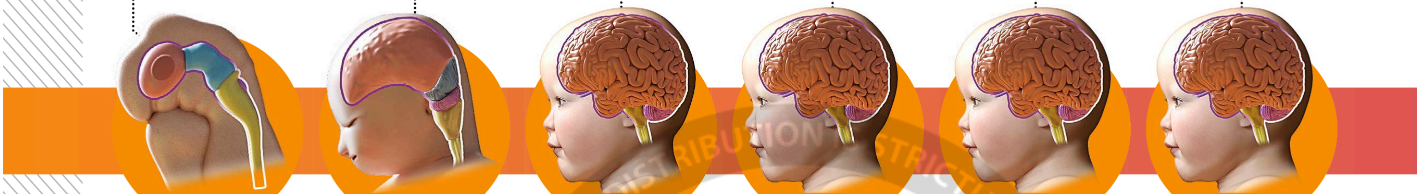
By two years old, the brain is already at 80 to 90 per cent of its adult size. This helps the infant learn many new skills in a relatively short time. The motor cortex in the frontal lobe grows significantly, enabling the planning, control and execution of physical movements.

## 5 LEARNING LANGUAGE

The brain makes sense of words and begins to organise them into sentences. Being able to speak in short sentences helps a child better express their wants and needs. As the brain picks up on the same words being used and repeated, it uses memory to make links and understand their meaning.

## 6 SOLVING PROBLEMS AND MAKING MEMORIES

The brain evolves to develop basic problem-solving skills, object categorisation and memories. This occurs because the brain is becoming more connected and enables multiple regions to engage in more complex thought processes. This includes working out cause-and-effect patterns.



35 DAYS AFTER CONCEPTION | 100 DAYS AFTER CONCEPTION | UP TO SIX MONTHS | SIX MONTHS TO TWO YEARS | TWO TO THREE YEARS | THREE TO SIX YEARS

The forebrain is the largest and most complex part of the newly formed brain. The higher cognitive functions take place in this part of the 35-day-old brain. It includes the cerebral cortex, thalamus, hypothalamus and basal ganglia.

The forebrain starts to take a larger, rounded shape, differentiating itself further from the other parts of the neural tube.

## 3 NEURAL CONNECTIONS

From birth, the brain undergoes rapid growth as new neurons are made. As it explores the world it has entered, a baby develops new neural connections. This causes the brain to double in size within the first year of life. By birth, a baby already has the basic reflexes to increase its chances of survival.

## 4 MOTOR SKILLS

By six months, a baby can sit unsupported, and by around 12 months begins to walk. Alongside these large movements, children this age develop fine motor skills, such as holding and stacking objects. Between 9 and 12 months, an infant's brain starts to comprehend object permanence. This is the understanding that objects continue to exist even when out of sight. During this period of life, the brain is constantly adding neural connections.

At ages two to three, the number of synapses reach their highest levels. Synaptic pruning takes place to improve the brain's efficiency. This means that extra and unnecessary neurons and synapses are eliminated. These include synapses that are rarely used and become weak. The brain activity they're associated with isn't needed and can be replaced.

One of the changes at this stage that improves the efficiency of thought processes and the ability to problem solve is myelination. This is when a myelin sheath, made of fat and protein, forms around nerves in the brain. Myelination improves conduction and sends electrical signals quicker throughout the brain.

By around the 24th week of pregnancy, scans show that babies move in response to sound

A child's brain uses touch, vision and spatial awareness when stacking objects

**DID YOU KNOW?** 60 per cent of a baby's energy goes into brain development

> "Every time an action is practised, more pathways are created in the brain, and the stronger they become"

Teenagers are thought to be more likely to take risks with unknown consequences than other age groups

## 7 LOGICAL THINKING AND CATEGORISATION

During these years, children enter the concrete operational stage of brain development. They become better at understanding events concerning other people and not just those they are directly involved in and experiencing. Some key features of the concrete operational stage include recognising that when an object changes size, volume or colour, it still keeps many of the same characteristics. Also, children are able to place items with matching characteristics into groups.

As pruning and myelination continue, neurons that are responsible for more complex thought processes are being strengthened. This helps a child single out relevant stimuli around them.

## 9 RISKY DECISIONS AND IMPULSE CONTROL

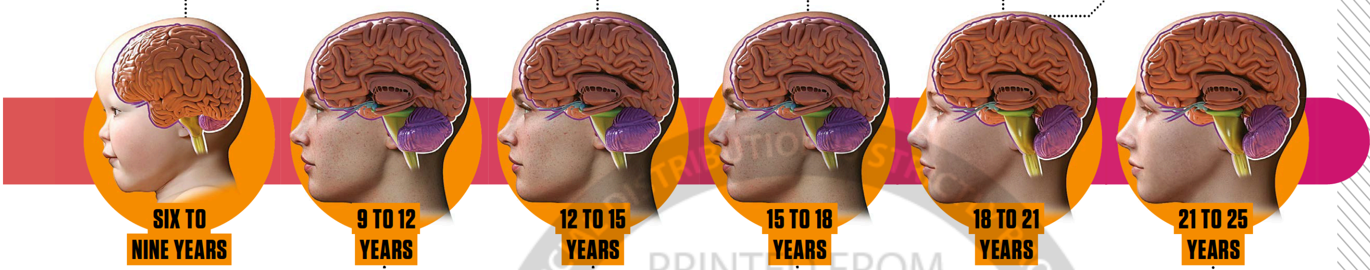
Teenagers get a bad reputation for making unwise choices, but there's a explanation. Puberty affects the entire body – brain included. New hormone levels cause more fluctuations in mood and impulsive behaviour. But the brain gets smarter too, developing a longer attention span, heightened abstract thinking and complex problem-solving.

As the limbic system matures and settles post-puberty, it becomes better at processing emotions and responding to the reward chemical dopamine that is released through romantic connections.

## 11 INCREASED SELF-ASSURANCE

At this stage, the brain is reaching peak maturity and the beginning of adulthood. This makes a person more trustworthy in making responsible decisions, better at planning for their future and confident in their own thoughts and decisions.

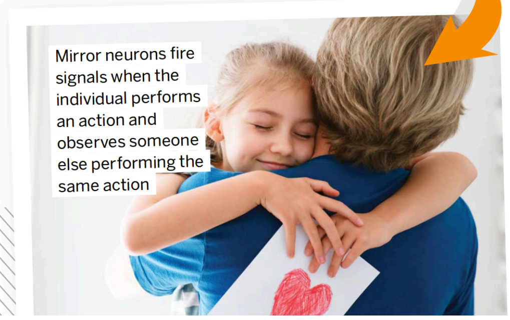
Grey matter, which contains the brain's cells and capillaries, reduces in size. Although the brain loses neurons, this makes the brain more efficient as there is more space for myelination. The brain is being refined to strengthen the most useful thought processes.




## 8 SOCIAL AND EMOTIONAL GROWTH

At this stage in life, an individual starts to display increasing signs of empathy as their brain becomes more emotionally intelligent. Building from past personal experiences and developing an understanding of the events that can cause different feelings, children between these ages are able to act more sensitively. Stronger friendships are generally formed at this stage of school life.

The frontal lobe reaches adult size. This increases the ability to form interpersonal relationships and manage emotions. The frontal lobe helps a person process positive emotions like happiness and gratitude and negative emotions like anger and jealousy.



Mirror neurons fire signals when the individual performs an action and observes someone else performing the same action

During puberty, the limbic system releases more hormones like oestrogen and testosterone. This rapidly developing part of the brain makes teens more likely to act on impulsive decisions and seek pleasure. The quickly evolving limbic system is in a state of imbalance compared to the more gradual progression of the prefrontal cortex, responsible for rational decisions. As a result, impulsive thoughts outweigh logic more often.

## 10 FORMING SELF-IDENTITY

The brain matures further during these years, giving individuals greater ability to reflect on experiences, behaviours and thoughts. Older teenagers are more capable of making decisions oriented towards the future. Maturation in emotional regulation also helps build romantic interest, as they can process stronger feelings better.

## 12 FULL MATURITY

Around these ages, your brain reaches full cognitive maturity. The brain is at its strongest in terms of critical thinking, performance and decision making. From this point, a person's cognitive skills remain relatively consistent. There is gradual decline as the years pass, but healthy eating and mental and physical exercise keep your brain thriving far into adulthood.

After maturity, the hippocampus makes new brain cells at a slower rate. The frontal lobe matures until around 25, at which point it is fully developed.