

# Inside the teenage brain

What differentiates a 14-year-old from their 40-year-old parent? Some people may say it's their taste in music, food and clothes. Other people may say it's the way they talk, what they do for fun and whether they watch the news. Neuroscientists think the answer, at least partially, lies in their brains. To explain why, we first need to understand what the brain is made of.

**Key words**

- brain
- neurons
- adolescence
- MRI scan

## What is the brain made of?

The human brain is made of 86 billion (86 000 000 000) brain cells known as neurons that work a little bit like the crocodile clips and wires used in science lessons. Just as crocodile clips can connect to other crocodile clips, neurons connect up to other neurons. We can call the two ends of a neuron end A and end B (see Figure 1). End A, the axon terminals, connect up to end B, the dendrites in another neuron. This connection is called a synapse.

When a neuron 'fires', an electrical signal runs from the dendrites, along the axon, to the axon terminal. This causes a tiny chemical signal (a neurotransmitter) to be released, from the axon terminal of the first neuron, across the synapse, into the dendrite of the second neuron, causing that neuron to 'fire'. This is very similar to electrons passing between the crocodile clips in electrical circuits. Additionally, whereas crocodile clips are covered with rubber to insulate the wires underneath, neurons are covered with an insulating layer of fatty cells called the myelin sheath. This layer of insulation helps to make the signal faster and more efficient, preventing it from being lost or weakened as it passes down the axon.

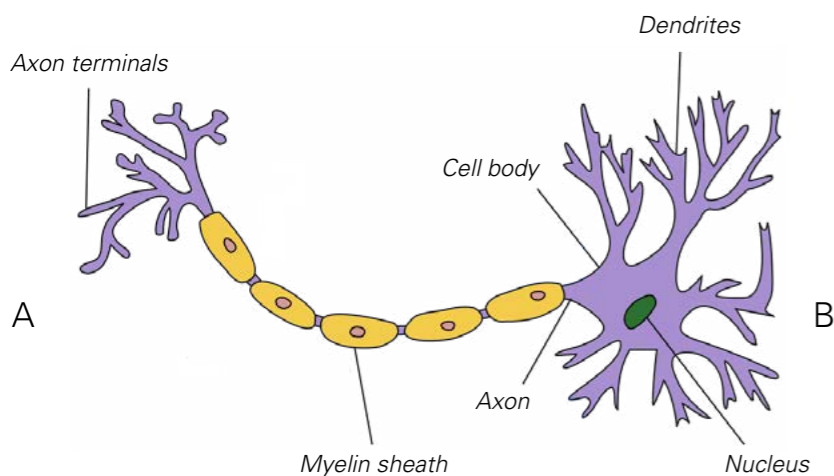


Figure 1 A typical neuron or brain cell

Within the brain a single neuron can connect up to thousands of other neurons, forming a vast, complex network of dendrites, axons and axon terminals. As can be seen in Figure 2, this network can be classified as two different types of matter; grey matter, containing the nucleus, dendrites and axon terminals (i.e. the connections); and white matter, containing the axons and myelin (i.e. the wires).

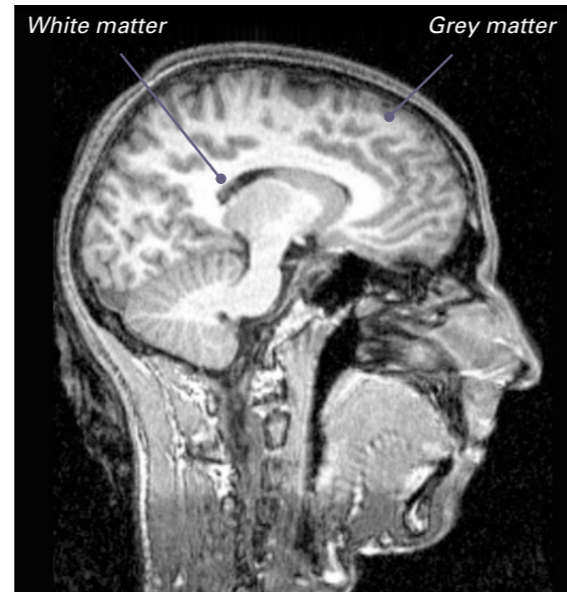


Figure 2 A structural MRI scan of the author's brain showing white and grey matter

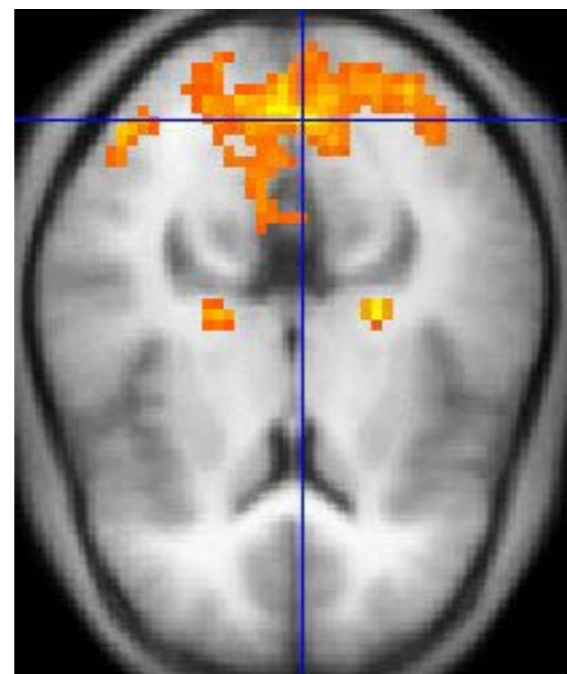


Figure 3 A functional MRI image showing brain activity. The warmer colours (yellow and orange) indicate an increase in blood flow. This image shows activation in the area of the brain responsible for vision.

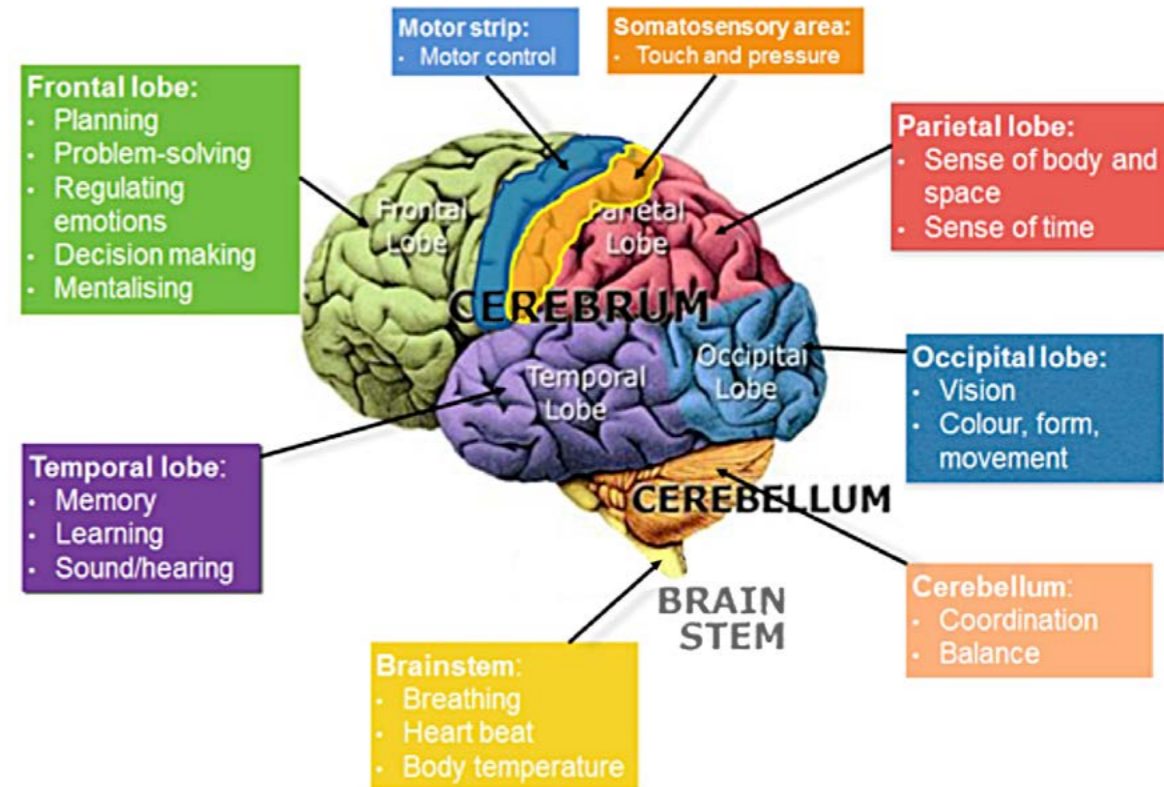


Figure 4 A map of the human brain showing the areas of different brain function

## How do you study the brain?

In the past we could only learn about the brain through studying patients who had sustained head injuries, dissecting their brains after they had died. Now, new technologies such as magnetic resonance imaging (MRI) allow us to look inside the living human brain. MRI scanners are giant ring shaped magnets that are hooked up to a computer. These magnets can be anything between 50 000 and 100 000 times the strength of the Earth's magnetic field. In the scanner, pulses of radio waves are sent into the brain where they are absorbed by the brain tissues. The energy of the absorbed waves is gradually re-radiated and this tiny signal is detected and fed into a computer to generate an image of either brain structure or brain function.

Different parts of the brain contain different concentrations of water (H<sub>2</sub>O). MRI scanners can detect the signal given off by the hydrogen (H) atoms; the signal differs slightly depending on the concentration of water in a given brain region. These signals are then used to produce an image of brain structure (Figure 2 opposite).

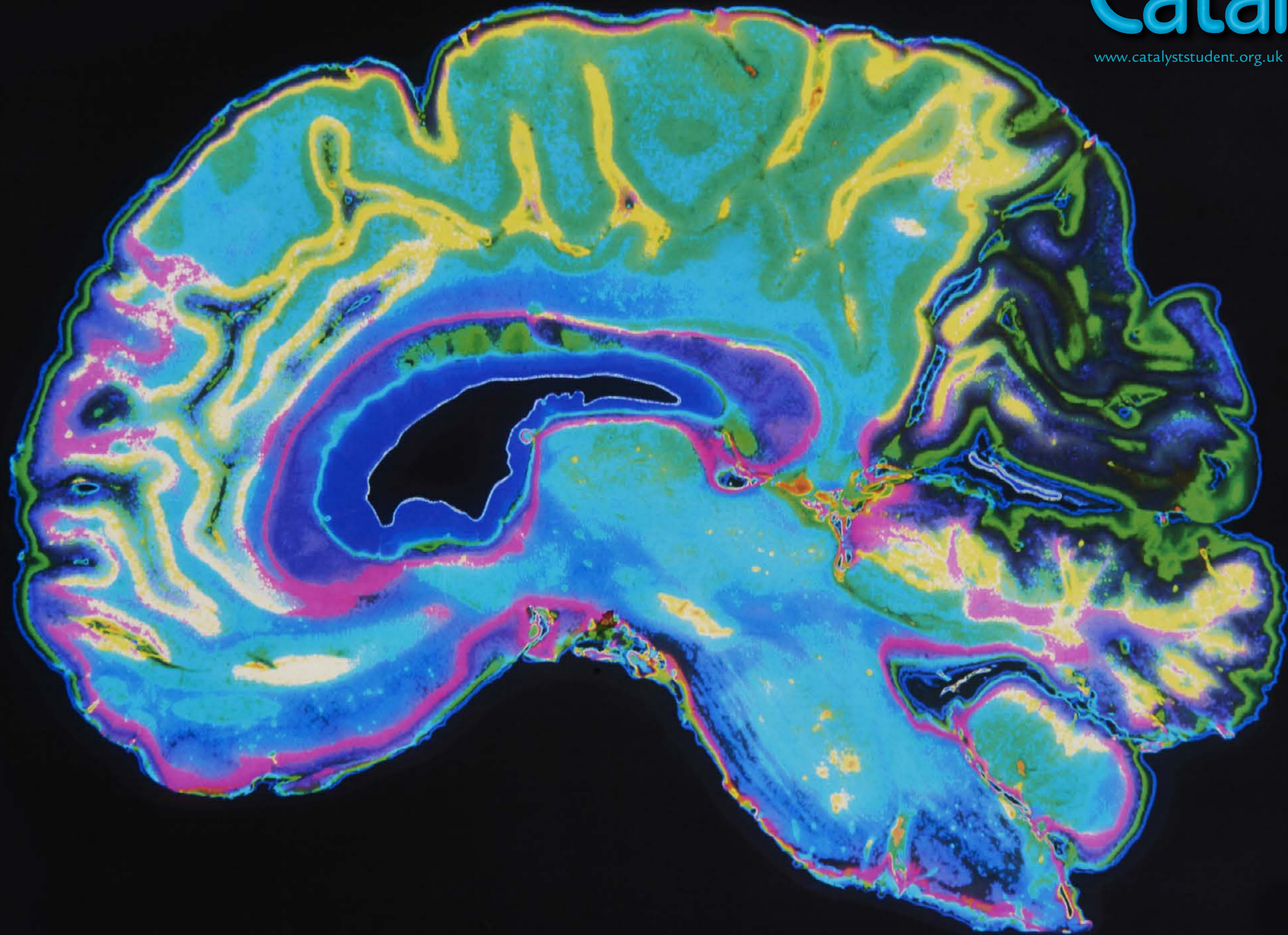
Like the muscles in your body, the brain needs blood to work properly. When neurons in one part of the brain start to fire, blood flows to that region of the brain to provide it with oxygen. MRI can be used to study where in the brain blood is flowing to and this can be correlated with the task a person is performing (Figure 3). This process is known as functional MRI and scientists have used it to

find out what bits of the brain 'light up' when we perform a range of tasks. This has given us a map of brain regions and the functions they are involved in (Figure 4).

## Brain changes during adolescence

Prior to the invention of MRI scanners, little was known about how the brain changed during the teenage years but now a number of studies have been conducted that shed light upon this issue. By scanning volunteers aged 5-20 researchers have found that white matter increases and grey matter decreases (Figure 5) during this time. The increase in white matter suggests that, throughout the teenage years, axons get covered in more and more myelin. The decrease in grey matter suggests that neurons lose connections with other neurons.

Lastly, researchers have found that different regions of the brain develop at different times (Figure 6). Notice in the figure how the yellow colour (indicating loss of grey matter) moves from the back of the brain to the front of the brain as we move through our teenage years. Regions of the brain involved in simpler processes, like vision and hearing in the occipital lobe, develop earlier than regions of the brain involved in more complex operations like thinking about the future and other people, in the frontal lobe. Together these factors result in efficient and specific brain networks that develop at different ages.



An MRI scan of the human brain.  
The original scan is greyscale; colours have been added to show the structure more clearly.

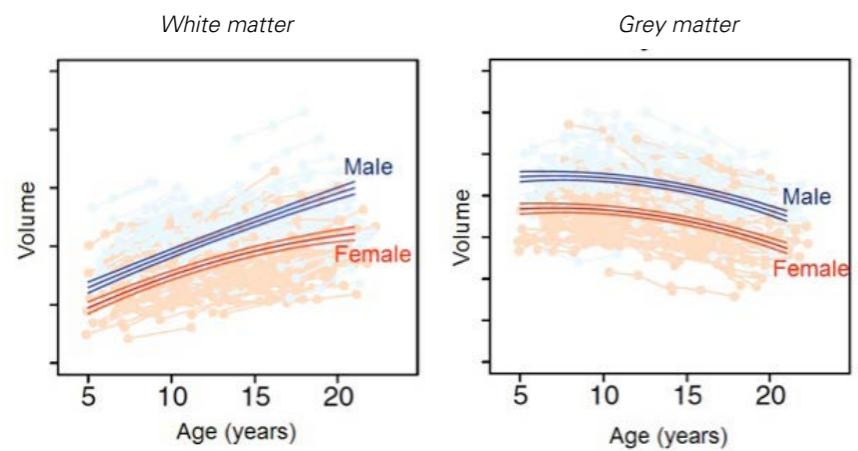
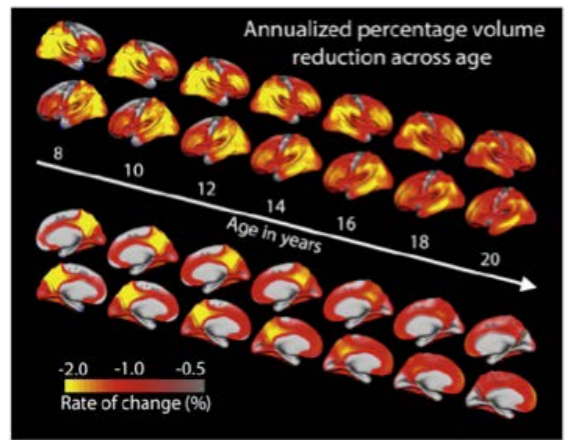


Figure 5 Graphs showing a white matter increase and b grey matter decrease during the teenage years.

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Figure 6 A heat map showing brain change during the teenage years. The top two rows show the outer surface of the brain (with the brain facing right then left); the bottom two rows show the inside surface (brain facing left then right). Yellow indicates a large change, red indicates a smaller decrease, grey indicates little change.

### How do brain changes affect behaviour during adolescence?

As we've seen, during adolescence the changes occur in the brain in regions responsible for planning, emotion regulation, understanding other people and a variety of other functions. What behaviours do you therefore predict may change during your teenage years? Researchers asked themselves this question and came up with a number of ideas. One group thought that teenagers may respond differently to social exclusion ('being left out of a group') as this uses both emotion regulation and our ability to understand other people.

To investigate the effect of social exclusion the group asked teenage and adult volunteers to play a game of catch on a computer with two other players who were not in the room and that they had not met (Figure 7). In one version of the game

volunteers were thrown the ball regularly (i.e. they were included) and in the other they were only thrown the ball once (i.e. they were excluded). Before and after playing the game volunteers were asked to answer some questions about their mood, this allowed the researchers to study how the game affected the volunteers.

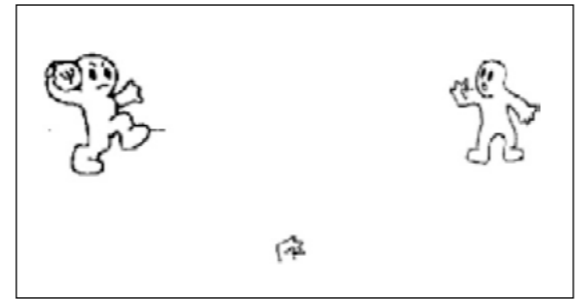


Figure 7 A virtual, on-screen game of catch. You are represented by the hand at the bottom of the screen, the other two players are shown above.

The researchers found that when volunteers, of any age, were not thrown the ball they reported feeling excluded. This suggests that the online game used in the study produced similar feelings to being left out of a game of catch in the real world.

Interestingly, only the teenage volunteers reported having a worse mood and greater anxiety after playing. This result suggests that teenagers are particularly vulnerable to the effects of social exclusion, as you might predict given that the frontal region of the brain responsible for mood regulation and understanding other people is still developing.

Another study used the same method except volunteers had their brains scanned whilst playing the task. This study reported that teenagers showed less activity in a region of the frontal lobe responsible for mood regulation, supporting the theory that differences in brain development may be responsible for differences in behaviour between teenagers and adults.

### What does this all mean?

As more and more studies report changes in the frontal cortices during the teenage years, researchers are asking more and more questions about how these changes affect teenagers' behaviour. Some of the main questions being asked relate to how other people affect the way we think and act, why teenagers take more risks than people of other ages and whether changes in our brain affect how we think and learn.

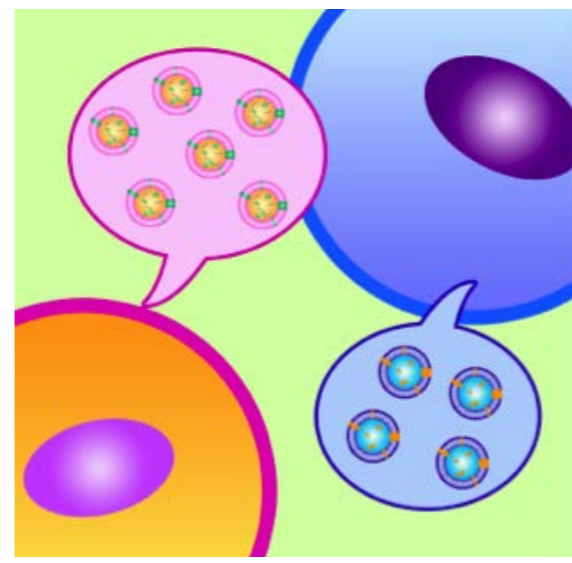
The field is still relatively young with new questions being asked all the time. Although this article has focused on the frontal lobes, large questions still remain about what effect changes in the parietal and temporal cortices have during the teenage years. What effect do you think brain changes have had on your behaviour?

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# Express delivery

## Good things come in small packages!

Have you ever waited all day for a parcel to arrive? Looking out of the window every five minutes in hope of a glimpse of the postman, you refuse to leave the house and watch the clock as the minutes slowly tick by. Parcels are also delivered to cells inside the body, but your cells do not wait all day; little packages, scientifically referred to as exosomes, are constantly being delivered to cells. The time between release of exosomes from the cells where they are produced to their delivery to recipient cells can be as short as 30 minutes. Exosomes are carried in biological fluids, most commonly in the blood.



Different types of cell produce different types of exosome.

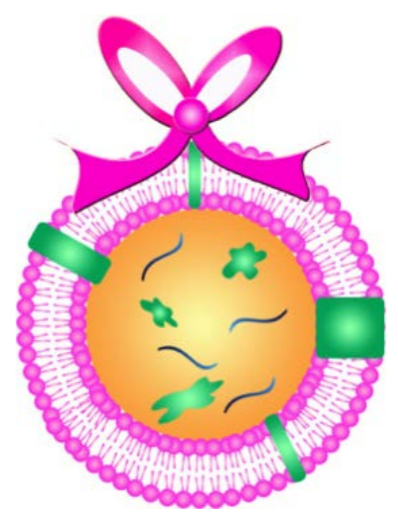
### Small packages

In order to maintain life it is vital that all 37 000 000 000 000 (37 trillion) of our cells communicate with each other. There are many processes through which this occurs. Hormones and neurotransmitters are the best described forms of intercellular communication; however exosomes also participate substantially in cell-to-cell signalling. Unfortunately, due to their excellent communication ability, exosomes also support disease development.

Exosomes are approximately 30-120 nm in diameter; this is 20 times smaller than bacteria, about the same size as a virus. In order to examine exosomes they are extracted from biological fluids by ultracentrifugation for at least 60 minutes at 100 000 g (g = acceleration due to gravity).

### Wrapping paper

Exosomes are delivered to neighbouring cells or distant organs in the same way that packages can be distributed both nationally and internationally. In same way that we might wrap a parcel with packaging suitable for the recipient - for example, (excuse the stereotypes!) pink wrapping paper for girls and blue wrapping paper for boys - exosomes do the same. They encase their cargo in a lipid shell which displays different proteins on the surface to ensure interaction with the correct recipient cell.



An exosome is a package delivering material from one cell to another. Its outer membrane is a double layer of lipid molecules.

Unlike most good delivery services though, it is likely that only a small percentage of exosomes reach their target cell. For this reason excessive numbers of exosomes are released to maximise the chance of signal transfer. Some exosomes may carry messages suitable for receipt by more than

**Key words**  
cells  
communication  
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microscopy