BigPicture on THINKING

ISSUE 4
SEPTEMBER 2006

An invisible gorilla? Find out on page 3.

Now you see it... Optical illusions such as this help us understand how the brain works.

Brain power.

The human brain may be the most complex structure in the universe.

It is so powerful that it is attempting to understand itself, through research.

The task is daunting. Some neuroscientists say that if the brain were simple enough to be understood, we would not be clever enough to understand it.

Yet the nature of human existence has fascinated us for centuries. It used to be **philosophers** who held sway on the nature of human life, the mysteries of consciousness, and other Big Questions.

In the past 20 years, though, a battery of new techniques has opened up new ways of exploring the brain. **Functional imaging** allows us to watch the brain in action; our understanding of the **biochemistry of nerve function** has blossomed; and the **genetic revolution** has allowed us to probe the function of individual genes and proteins.

These techniques are shedding light on the very essence of human life – how we feel, how we think and how we act. Even the most difficult question of all, the nature of **consciousness**, is beginning to be unravelled.

While exciting, these developments also raise unease. Can we really see ourselves simply as ‘biological computers’? If we understand the basis of our mental self-image, or identity, can we (and should we) seek to change ourselves into something else? And if our actions are just biology in action, how responsible can we be for what we do?

FIND OUT MORE

wellcome trust

LOOKING AND LEARNING

FAST FACT
The adult brain contains around one hundred billion neurons and even more support cells.

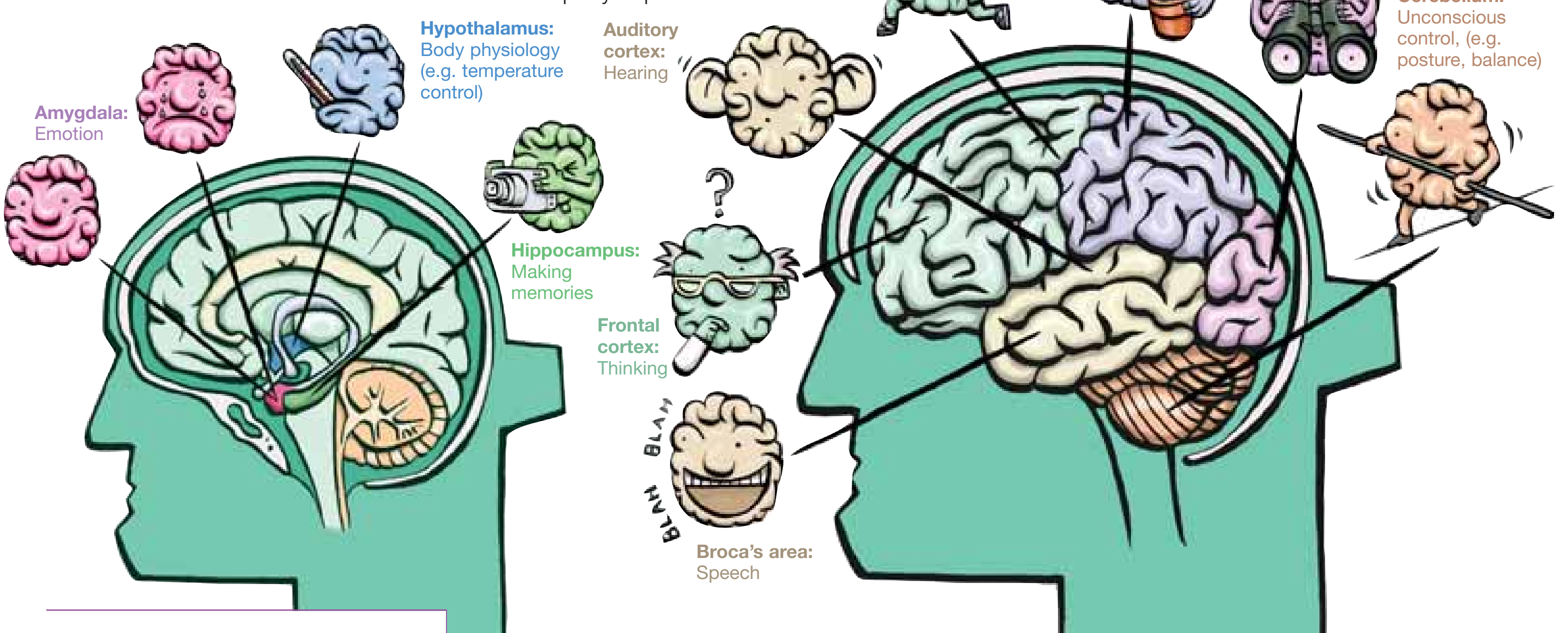
Our brains are staggeringly clever things. They can take in incredible amounts of information, filter out what is not needed, store away information for future reference, recall past experience, and control what the rest of the body does.

What's more, they do all these things simultaneously, every waking second of the day.

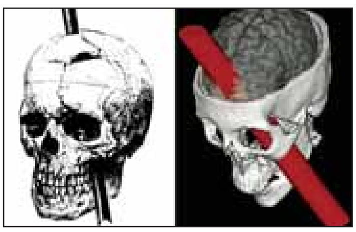
We are just beginning to work out how the brain manages these incredible feats, and how it is that single cells – mainly **neurons** – acting together can do so many wonderful things.

The brain at work

The brain operates by **division of labour**: different areas are specialised for different functions (see diagram). However, these are not independent republics – connections between them are equally important.



Many insights have come from people whose brain injuries have altered their behaviour. The classic case is that of railway worker **Phineas Gage**. In 1848 an explosion blew a metal rod through his skull, removing a large chunk of forebrain. Gage survived but his personality changed dramatically. Formerly a reliable worker, after the accident he became a drunken drifter, aggressive and impulsive, his ability to control behaviour lost with his prefrontal cortex.



TYPES OF MEMORY

1. **Procedural memory** or 'how to' memories (e.g. how to swim or ride a bicycle) are stored in the cerebellum and putamen.
2. **Emotional memories** such as those related to phobias and flashbacks are initially encoded in the amygdala, which then influences other memory-encoding regions.
3. **Episodic memory** is made up of the personal memories, our 'filmic' recollection of past experiences. This is encoded by the hippocampus and stored in the cortex.
4. **Semantic memory** is for facts. They are registered by the cortex and end up in the temporal lobe.

We also have an unconscious (or '**implicit**') memory – we may unconsciously react to a stimulus differently if we have experienced it before, even if we are not aware that we have seen it before.

The mind's eye

Vision is our most crucial sense. We rely on it for survival but just how reliable is it?

It is tempting to think of our eyes as mini-cameras constantly filming the outside world. In fact, vision is nothing like that. The seamless view of the world is an illusion created by the brain after it has dismantled the input it receives from the eyes.

For a start, we do not look at a scene in a steady way. Instead, our eyes constantly flicker back and forth (involuntary movements known as **saccades**), scanning scenes in detail. From this constantly shifting input, the brain builds up a coherent mental picture corresponding to a scene.

We now know that neurons in our brain specialise in recognising particular aspects of a scene, such as edges or dots or motion. Each neuron has a '**receptive field**', an area around it that is sensitive to its favoured stimulus (like a detector attached to a security light, which can detect movement within a particular area of ground).

Then, in a computational task of staggering complexity, the brain integrates all these signals to create a visual impression of the outside world.

Pay attention

Another key difference between the visual system and a camera is the phenomenon of **attention**. There is so much going on in the world that the brain has to filter out unnecessary input. One way it does this is by focusing on (or '**attending**') to a small area at any one time.

We are not very aware of this, partly because our peripheral vision is sensitive to movement, so if something noteworthy happens there we are quick to notice. But it means we take in much less of a scene than we might imagine.

A nice example is a study in which volunteers were asked to watch a videotape of people playing basketball. They were asked to count the passes made by one of the teams. Afterwards they were asked if they had noticed anything unusual.

Fixated on counting, almost half failed to spot a woman dressed in a gorilla suit who stopped to face the camera, banged her chest and walked off.

Filling in

The other big difference between the brain and a camera is that the brain guesses more. When presented with incomplete information, it fills in the gaps, making assumptions about what should be there given the rest of the visual input it is receiving.

This **filling in** can be useful. The visual system is often trying to extract patterns. So when it finds one but with a bit missing, it fills in the missing space, so we get a complete coherent picture. But it sometimes leaps to the wrong conclusion. Can we believe our eyes? Not always.

Learning and memory

The brain structures, neurons and even molecules and genes associated with memory are beginning to be identified.

We are in many ways the sum of our experiences. How we act and behave depends not just on what is happening to us now but also on what has happened to us in the past. We learn and we can make memories.

Nearly all animals can learn. A simple form of learning is **association** – some kind of sensory stimulus is 'remembered' and an animal's behaviour changes the next time it encounters that stimulus. The classic example is provided by **Pavlov's dogs**, who were given food every time a bell rang. Eventually, they began to salivate in response to the bell on its own.

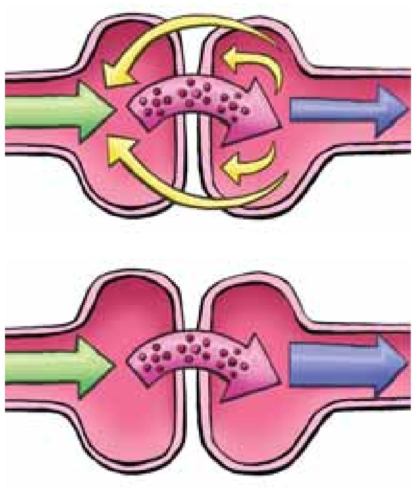
Human memory is more complex – in fact, we have several different types of memory, involving many parts of the brain (see box, below left).

Making memories

But what exactly does a 'memory' look like in the brain? Again, it is difficult to liken it to anything everyday such as a photograph in an album.

Memories are hard to pin down, as they involve a constellation of neurons connecting together in different patterns. Putting away the memory of Christmas day is produced by millions of neural brain patterns firing: some for the taste of Brussels sprouts, others for a favourite carol. The pattern remains after the stimulus disappears and a memory is born.

In terms of mechanisms, memory making is thought to depend on neurons strengthening their connections to one another – 'remembering' that they have been in touch before (see figure above).



When a nerve impulse (green) arrives at the end of a neuron, neurotransmitters ferry the signal across the synapse (pink), setting off a new action potential (blue). Signals are also sent back to the original neuron (yellow, top) so that the next time a nerve impulse arrives (bottom) the second neuron reads more strongly.

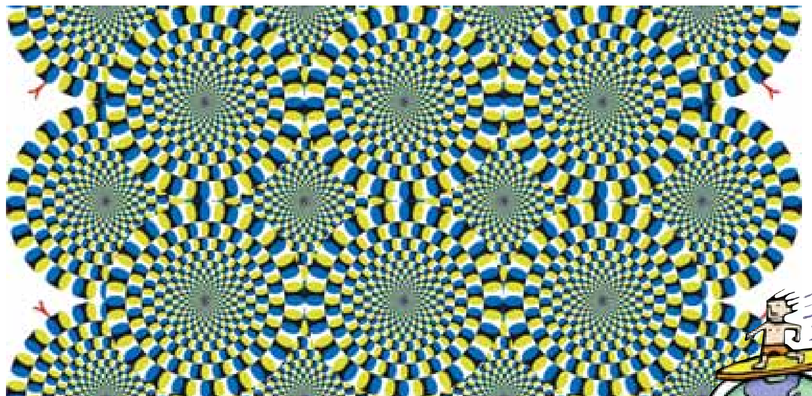
STRANGE TIMES

Some people with brain damage, or by a quirk of fate, lack a very specific mental function.

Blindsight
Remarkably, some patients have no conscious vision but can still point at a coloured dot on a screen when forced to guess. This suggests that we can 'see' things without being consciously aware of them.

Synaesthesia
Some people don't just hear sounds – they see them too (see page 12).

Prosopagnosia
People with **prosopagnosia** are unable to recognise **faces**, suggesting that there is a 'module' in the brain specifically dealing with face recognition.



Akiyoshi Kitaoka
www.ritsumei.ac.jp/~akitaoka/index-e.html

Optical quirk – www.ophtasurf.com/en/bestillusions5.htm
This optical illusion illustrates how our perception can be tricked – in this case into believing something is moving. Optical illusions have told us much about how the brain interprets scenes, for more details (and illusions) see...

www.wellcome.ac.uk/bigpicture/thinking

WHY DO I THINK AND FEEL?

We sometimes think of a brain as a powerful computer. But it is much more than that. Our brains are also home to our feelings, moods, personalities and character. Courage is not found in the heart but in our brain's neural networks.

Emotions

We are emotional creatures. The brain is not just a logic machine, but also handles emotions – some of the most powerful drivers of human behaviour.

Emotion is important to how we experience life. Love, fear, anger, disgust are central to human experience. This handful of raw emotions, in different combinations, adds spice to our existence, defines many of our goals and influences our decisions.

In their crudest form, emotions help survival. Fear and disgust drive us away from possible sources of harm, such as predators or rotten food; love helps us reproduce. They have a profound impact on us, affecting almost all aspects of our behaviour and thinking.

One impact is on **attention** (see page 3). We detect emotional stimuli – faces with positive or negative expressions, or spiders and snakes – much quicker than neutral ones.

Oddly, though, functional imaging (see page 6) has shown that the brain also reacts to emotional stimuli *before* the nature of stimuli has been explicitly recognised, or even without any conscious recollection that we've seen something scary (for instance).

The key brain region here is the **amygdala**, which receives visual input independent of the main vision processing areas of the brain. If it detects frightening stimuli, it sends messages to other parts of the brain, triggering a series of responses – making us 'frightened'.

Memories are made of this

As well as preferentially focusing on emotional stimuli, we also remember them better. We tend to remember not the mundane but the events that are emotionally charged – the good or the bad. Again, memory enhancement seems to depend on activity in the amygdala.

Sometimes, though, people do not want to be reminded of emotionally charged experiences. People with **post-traumatic stress disorder** (PTSD) suffer from unwanted flashbacks and intrusive memories of their trauma. Interestingly, creation of traumatic memories depends on a particular neurotransmitter (noradrenaline), and a drug that blocks its action – **propanolol**, more usually used to slow the heart – can prevent traumatic memories being laid down. There is interest in using this as a drug to treat, or even prevent, PTSD.

Feelings, nothing more than feelings

Neuroscientists see **emotions** as well-described and consistent brain responses. They translate into subjective experiences we know as **feelings**. These derive in part from the physiological changes created by the emotional stimuli, which are registered by sensors of the body's internal state (internal organs, energy levels etc.).

It is likely that the brain systems handling emotions are not the same as those responsible for feelings. For example, some people with amygdala damage do not show emotional responses but still experience feelings.

Another distinction is that feelings seem to have more influence over long-term behaviour and decision-making. So our choices depend in part on our past feeling states.

Highly illogical

Emotion and reason are often thought of as enemies – a battle between cold, hard logic and irrational, emotional decision-making.

In fact, though, emotional responses may enhance our decision-making ability, for example by helping us to make value judgements about people based on their facial expressions or because of an awareness of our current bodily state.

FAST FACT

Length of myelinated nerve fibres in brain = 150 000 to 180 000 km (enough to go round the Earth about four times)

WHAT GOVERNS MOOD?

Our mood, or predominant emotion, is governed by several neurotransmitters produced in our bodies.

Serotonin enhances mood by reducing depression and anxiety. Antidepressants that increase serotonin levels are now widely used to treat depression. Interestingly, low serotonin levels have been found in suicide victims.

Dopamine, nicknamed 'the pleasure chemical', promotes a feeling of bliss. This explains the attraction of alcohol, nicotine, and drugs such as cocaine, all of which increase dopamine levels.

Playing sports makes us feel better due to the release of noradrenaline, another feel-good chemical. Pleasure is also increased by endorphins, the body's natural painkillers, which are also released during exercise.

Other chemicals, such as GABA and histamine, may also influence mood. Our final mood is governed by complex interplay between all these chemicals, with each chemical's level being modified by factors such as heredity, environment, lifestyle – and even diet.

NUN BETTER: Is happiness actually good for us? A study of nuns suggests it may be. The nuns had written autobiographies in their 20s. When these were scored for positive or negative emotions, those most positive lived on average ten years longer than those expressing the least positive feelings.

FAST FACT

Total number of neurons in cerebral cortex = 10–20 billion (about three times the population of the Earth)

Happiness

Research has tended to look at the dark side of life – anxiety, depression and so on. The flipside, happiness or contentment, has been neglected, but is now receiving more attention.

Money can't buy me love, sang the Beatles, and it can't buy much happiness either. A little bit extra seems to help, but above a fairly low threshold more money does not add to our happiness (though around the world, a great many people will be below this threshold). Relative wealth seems to be crucial – is there someone better off than us? As Samuel Johnson noted: "Life is a progress from want to want, not from enjoyment to enjoyment."

Similarly, Ghana, Mexico, Sweden, the UK and the USA all share similar life satisfaction scores even though average income varies ten-fold between the richest and poorest countries.

In 44 countries surveyed in 2002, **family life** provided the greatest source of satisfaction. And it's good for us too: married people live on average three years longer and enjoy greater physical and psychological health than the unmarried. More generally, the extent of our **social network** is the best predictor of happiness.

Other important factors include **satisfaction with work** and working conditions and extent of **choice** and **political freedom** in the society in which we live.

Can we do anything about our state of happiness? Good fortune can raise our mood temporarily, but we gradually return to some kind of baseline, suggesting that we may have some inbuilt happiness level. If we do want to be happy, it is best to concentrate on **social connections** and **fulfilling work** rather than the pursuit of wealth – or you could move to Bhutan, where the King recently announced that his nation's objective would be **gross national happiness**.

Trust me, I'm a scientist

Although we do fall out occasionally, human society is notable for its degree of cooperation between individuals.

Cooperation presents a difficulty for **evolutionary theory**, which at its simplest suggests that individuals should just look out for themselves. More sophisticated analyses, though, show that helping others can bring you benefits – the phenomenon of **indirect reciprocity** – you help somebody, somebody else helps you.

This analysis can explain how factors such as reputation, perceived moral character and other aspects of social communication can develop.

We know a little about the brain systems responsible for these phenomena. Logical reasoning plays a part but is not the whole story. One interesting player is the hormone **oxytocin**, which encourages bonding. When given to subjects playing a risky investment game, it makes them more trusting of their (unidentified) partners.

Probing personality

Can personality be studied in a reliable way?

We all recognise that people are unique, with distinct personalities. We also have an urge to categorise, and numerous approaches have been taken to analyse personalities and draw out common themes.

Personality is sometimes broken down into a number of qualities. The most common tests focus on four or five qualities – like the so-called **Big Five**:

Openness to experience	**A**greeableness
Conscientiousness	**N**euroticism
Extraversion	

Subjects complete carefully constructed questionnaires and end up with scores for each of the categories. A variant of this method is the **Myers–Briggs** model:

Extraversion	vs	**I**ntroversion
Sensing	vs	I**N**tuition
Thinking	vs	**F**eeling
Judging	vs	**P**erceiving

These tests seem to be fairly robust – if people do the test on different days, their scores tend to be very similar and they are not influenced much by mood.

Are these measures of value? They can be useful tools for **self-awareness** and help people understand and interact with others. They may also help to identify people susceptible to **mental health problems**. For example, psychological measures provide a very good way of picking out people likely to suffer from post-traumatic stress disorder after a traumatic incident.

One problem with such personality tests, though, is that individuals can end up being pigeon-holed into a certain 'type' or behaving in ways they think are expected of them.

SEEING THINGS: The Rorschach inkblot test, one of the earliest personality tests. People look at inkblots and quickly say what they think they show. But analysis of the test is subjective too, as interpretation varies with the psychologist.

Mental health – broadly speaking, three kinds of mental health disorder exist.

- **Mood disorders** – Depression, bipolar disorder (manic depression). *Long-term disturbance to mood.*
- **Anxiety disorders** – Post-traumatic stress disorder, social phobia, phobias, obsessive–compulsive disorder. *States of excessive anxiety interfering significantly with daily life.*
- **Personality disorders** – Antisocial personality disorders, borderline personality disorder. *Inflexible and problematic patterns of thought and behaviour. Less consensus on their medical nature.*

ON THE WEB

Find out more at

www.wellcome.ac.uk/bigpicture/thinking

WHO AM I?

We can usually tell when we have spoken and when we have listened to others. Or whether we have moved our arm or someone else has moved it for us. Our brains can distinguish 'us' from 'them'.

More philosophically, we also have a **perception of ourselves** – our personality and character. That, more than our physical form, is what we mean by 'me'. We have a sense of ourselves occupying our body and can imagine an existence outside it.

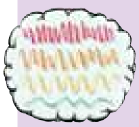
Because these impressions are **subjective** – existing just within our own heads – they are very difficult to study. Do you feel pain in the same way as I do? Or experience the colour red in the same way?

We are beginning to discover how the brain creates these internal impressions, including those of **self and self-identity**.

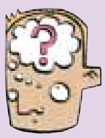
WAYS OF SEEING

PSYCHOLOGICAL STUDIES
Assess people's behaviour or responses under controlled experimental circumstances.
Example: Experiments exploring our approach to risk.

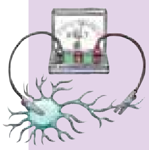
FUNCTIONAL IMAGING
(e.g. functional magnetic resonance imaging, fMRI)
Measures brain activity during particular tasks.
Example: Reveals which areas are active when we read and comprehend language.



EEG (electroencephalography)
Recording of brain waves through the scalp; gives clues to timing, locality and type of brain function.
Example: Monitoring brain activity during sleep.

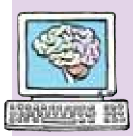


NEUROPSYCHIATRY
Assessing impact of damage to specific parts of the brain.
Example: Damage to Broca's area removes ability to speak.



ELECTROPHYSIOLOGY
Studying the firing patterns of neurons and their response to different chemicals.
Examples: Understanding role of neurotransmitters in memory.

ANIMAL STUDIES
Links between genes, neurons, brain and behaviour can be studied in animals that can be genetically engineered.
Example: Neuron function in the sea slug; neural pathways controlling sexuality in the fruit fly.



MODELLING
Using computers to model the behaviour of neurons acting together.
Examples: Neural networks mimicking brain activity leading to epileptic seizures.

Times past

The Greek physician Hippocrates, who lived around 400 BCE, was the first to emphasise the importance of the body in generating functions such as memory, thought and reason.

He proposed a purely materialist account of body and mind in which our health and behaviour are governed by four '**humours**' – blood, phlegm, bile and black bile. Lower passions such as greed and lust must reside in the liver and guts, reason in the head. These ideas persist – we still speak of making decisions according to our heart or our head.

The philosopher **Plato**, who lived during the same period, rejected this idea. He believed in the soul. These competing theories prevailed until the 17th century, when French philosopher **René Descartes** (above) conceived the idea that there is a total split between the conscious mind and the body – the **dualist concept**. He believed that voluntary thought and movement are the properties of an immortal soul.

The dualist concept has endured for centuries. Its success is probably because, intuitively, we find it hard to accept the idea that 'mere' brain tissue can produce feelings and experiences like love, imagination, dreams and passion.

For ages, scientists were reluctant to tackle the issue of mind and consciousness because it was either too philosophical or just too elusive to study experimentally. What actually is 'consciousness'? How can you measure it?

What is consciousness?
Philosophers have spent centuries debating the nature of consciousness. It remains a highly controversial topic, with plenty of disagreement.

Consciousness encompasses feelings and experience, many of which are purely subjective (the sensation of taste for example, or 'the redness of red'). These are known as **qualia**. A major problem for science is to understand how these experiences can arise from the brain's raw material – the neurons, other types of cells and surrounding fluids and intercellular 'glue' inside our skulls. Scientists often talk in terms of an '**emergent property**' – something that happens collectively that would not have been predicted on the basis of what is known of the individual units.

Some neuroscientists call the subjective element the 'hard' problem of consciousness. Because it is 'private' to an individual, some argue that it is not something that we will ever be able to explain meaningfully.

More conveniently, consciousness can be likened to **awareness** – of one's self and surroundings. It is sometimes divided into **phenomenal consciousness** (P-consciousness), an awareness of what is going on now, and **access consciousness** (A-consciousness), reflecting internally, drawing on past experience and memory.

ABNORMAL VERSUS NORMAL

Neuroscience research has tended to focus on abnormal function – such as Phineas Gage (see page 2), 'memory men', or people with aphasia. While this is still an important element of research, greater attention is now given to studies of the 'normal' – what is going on inside the heads of people who are not judged to have any clinical problem. This is shedding light on brain function, but also helps us to judge when something should be classified as 'abnormal'.

The science of consciousness

Consciousness is one of the last great mysteries of modern science.

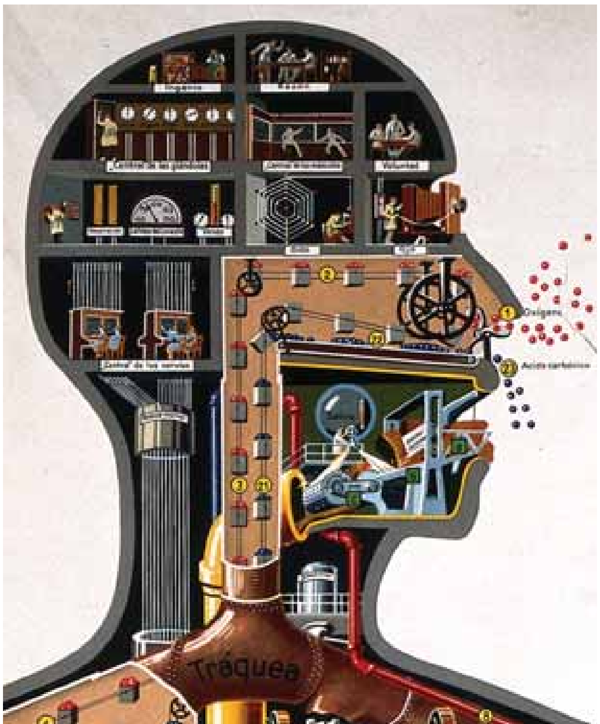
Zoom into the brain, and you see a dense network of cells. The vivid quality of our conscious experience, our emotions, imagination, dreams and mystical experiences, are all underpinned by a flurry of electrical activity, neurons firing and interacting in different sets of patterns. Every aspect of the mind, most neuroscientists now believe, can be explained in mechanistic terms.

Francis Crick was one of the first to propose that consciousness or awareness is underpinned by brain activity alone – what he called his 'astonishing hypothesis'. In the 1960s, he argued that neuroscientists must search out the neurons that fire specifically during conscious moments – the so-called **neural correlates of consciousness**.

Of course, many neurons are active when we are conscious but that doesn't mean they are necessarily contributing to a conscious experience. One way to narrow the search is to compare a sensory system operating with or without conscious awareness (e.g. by using backward masking; see right). An alternative is to examine the impact of different types and doses of **anaesthetics**, which can selectively remove aspects of conscious experience.

Although not certain, there is a growing consensus that consciousness is not located in one specific part of the brain but is distributed around the brain in a kind of network. Some liken it to a virtual '**workspace**' that draws upon unconscious neural activity all around the brain, assimilating our conscious view of the world.

This view is a little like a security guard using security cameras to monitor what is going on around a building. This is curiously similar to an early metaphor for consciousness, in which a tiny man – the **homunculus** – sat in the brain absorbing information from the outside world and deciding what the body should do.



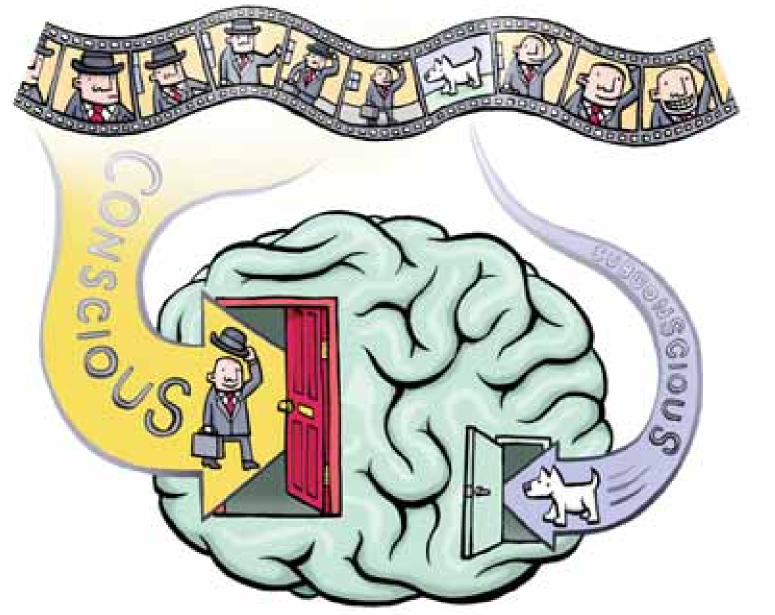
DIVISION OF LABOUR: A 1930s view of the body. The technology may look antiquated, but the idea of 'division of labour' in the brain is still valid.

Unconscious vision

Vision is so important to us that it tends to dominate research on consciousness. To get at the heart of a conscious experience, we need to compare the brain's response to consciously and unconsciously perceived stimuli. But how do you have an unconscious visual experience?

The usual trick is to apply **backward masking** – a visual stimulus is shown to a subject very briefly and is then replaced by a strong second stimulus. This dominates the conscious visual response, 'masking' the original stimulus. Subjects cannot say, or even guess, what it is they were shown.

However, psychological tests and brain imaging shows that they have registered the image. If it was an angry face, they react much more strongly when shown it again than if they are seeing it for the first time – even though they do not 'know' they have seen it before.



Sleep and consciousness

During sleep, our brain slips into autopilot. The key change, it seems, is the loss of communication between different areas of the brain.

Each day, when we fall asleep, we depart consciousness. The sleeping brain has long puzzled scientists, who have noticed that even though consciousness fades the brain remains active.

Vivid dreams are similar to a 'virtual reality' experience. Intensely visual dreams light up the visual cortex, **nightmares** trigger activity in the **amygdala**, and the **hippocampus** flares up from time to time to replay recent events. The pathways that carry signals from the auditory cortex are also active, as are the motor areas. But despite this symphony of brain activity, people still have no conscious experience.

Scientists now believe they can explain why. With the onset of sleep, the connections between brain areas weaken and the information, though present, is not integrated. So, when a powerful magnet is used to stimulate the brain specifically in the premotor area, activity spreads to the rest of the brain when people are awake but remains locally confined when they are asleep.

A similar uncoupling could explain how **anaesthetics** work. Recent studies suggest that neural activity does not stop, but the brain no longer integrates information from different areas of the brain.

Sleep yourself better – Want to improve your dance moves? Finish a crossword? Then take to your bed. Far from shutting off, the brain uses sleep as a time to lay down memories and replay the day's activities. We may not know it, but we wake up better prepared for the world than when we went to sleep. Find out more at

ON THE WEB

www.wellcome.ac.uk/bigpicture/thinking

WHO ARE YOU?

As social animals, we interact with other people, cooperating, negotiating and occasionally confronting.

Our success as a species owes a lot to our ability to work together – fossil evidence suggests that early humans were a tasty treat for predators. As a collaborating pack, we were safer and could become hunters rather than hunted.

Collective action depends on effective **communication**. Although we have developed **language**, we also draw important **non-verbal information** from others – reading facial expressions, for example – and draw inferences about people's **intentions** and **motivations**.

If we have problems with these forms of **social communication**, we can have great difficulty functioning as part of society.

MIRROR, MIRROR

The discovery of mirror systems has helped us understand the planning and imagining of actions.

When we move to strike a tennis ball, for example, our actions are guided by the brain's motor control systems.

Recently, it has become clear that these same systems are also active when we imagine making an action in our head (reliving a perfect cross-court volley, for example). And, remarkably, they also light up when we watch someone performing an action.

The key difference is that the levels of activity are lower than when we actually perform the action – so muscular contraction is not actually triggered. Because the systems reflect the 'real' activity, they are known as mirror systems.

The system is extraordinarily specific. Mirror systems fire when someone sees a person making an arm movement, for example, but not when they see a robotic arm move. It is possible that this activity allows us to put ourselves in others' positions, experiencing (but to a lesser degree) what they are experiencing. They may therefore help us to infer the intentions of others.

Face the facts

We draw important information from people's faces and facial expressions.

It is said that the route to a person's soul is through their eyes. There is much truth in that, as we extract considerable information about people's moods and feelings from their faces, particularly the eyes.

We seem to have specific face-recognition modules in the brain, emphasising their importance to us. So when we recognise someone it is usually through their faces and not, for example, their body posture. Further evidence comes from people with prosopagnosia (see page 3) who specifically cannot recognise faces. Even sheep seem to recognise other sheep by their faces.

The presence of a face-recognition module could also explain why we tend to 'see' faces in, for example, toast or on the moon – the brain interprets a face-like pattern of light and shade as a genuine face.

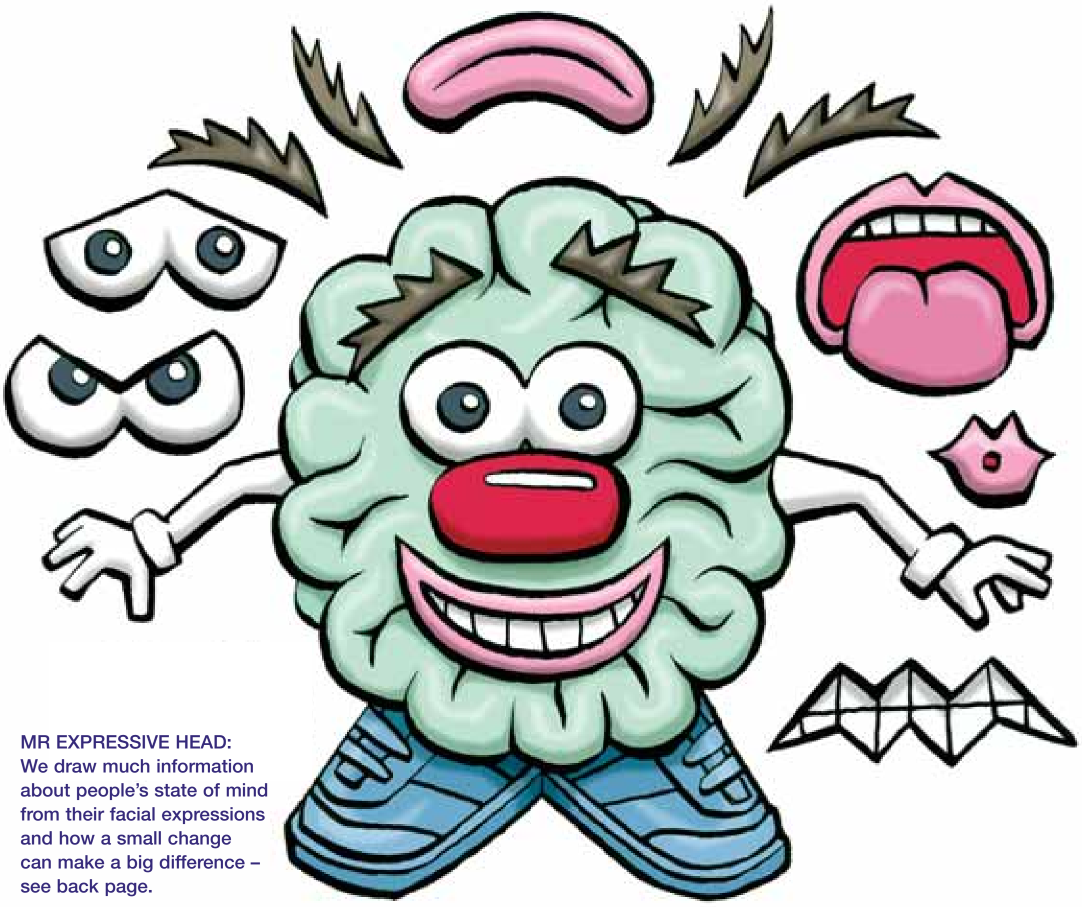
Charles Darwin proposed that facial expressions were common to all humanity – even remote populations laugh the same way we do. We can all tell when someone is happy or sad or angry from the expression on their face. (Although this ability is not well developed in children; it improves as children get older, dipping slightly at adolescence. Younger children are generally less able to pick up subtle facial cues, one reason why their behaviour is less influenced by others.)

There are some suggestions that, as well as the stereotyped major expressions, there are many '**micro-expressions**' that convey meaning. The brain picks these up subconsciously.

CHARLES DARWIN PROPOSED THAT FACIAL EXPRESSIONS WERE COMMON TO ALL HUMANITY

Expressions give away information about us, but so does the basic structure of our face. **Sex**, **age** and **ethnicity** can all be assessed from faces. A **masculine** face is very different from a **feminine** one. Even our sense of beauty is strongly linked to facial features – a **symmetrical** face is usually seen as more attractive.

Through the ages, people have tried to take this further and infer character from faces. Was there a '**criminal face**' that could be used to identify possible miscreants? Despite a huge amount of work, no convincing links have ever been found.



MR EXPRESSIVE HEAD: We draw much information about people's state of mind from their facial expressions and how a small change can make a big difference – see back page.

You or me?

If our grasp of 'us and them' goes wrong, we can have considerable problems in life.

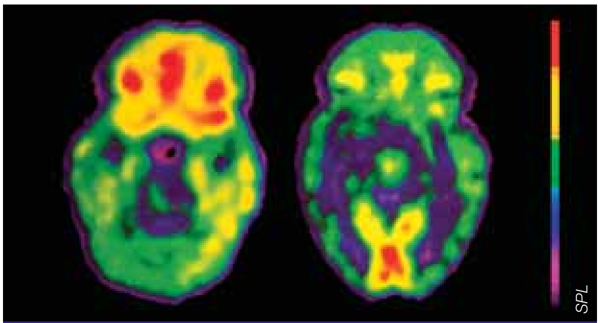
Most of us take for granted that we can tell the difference between an action we have generated ourselves and one forced on us by another. And most of our **social interactions** with other people are not consciously thought about. But if our brains are not adept at these activities, life can be very challenging.

People with **schizophrenia**, for example, show several distorted ways of thinking during **psychotic episodes**. A common symptom is to believe that one's actions are being controlled by external forces. In brain scans, this is apparent as activity patterns characteristic of externally applied (rather than internally generated) movements. (An odd consequence of this is that, during a psychotic episode, people with schizophrenia can tickle themselves: they do not perceive the hand doing the tickling as their own.)

Similarly, people with schizophrenia will sometimes hear **internal voices**, urging them to do things. Brain imaging again shows brain activity corresponding to external sounds, not internal dialogue.

A third common symptom in people with schizophrenia is **paranoia**, a belief that people are following you or looking at you all the time. This appears to be an error in processing information from others – a casual glance ignored by most is interpreted as evidence of a deep interest and desire to cause harm.

It is possible that impaired pick-up of social cues also underpins other forms of **behaviour disorder**. People with **antisocial personality disorder** (psychopathy) seem less able to identify fearful expressions, so will be less able to tell that their behaviour is having a negative impact on people. Some symptoms of autism, too, seem to be linked to defective recognition of social cues (see above right).



SCHIZOPHRENIA: Coloured positron emission tomography (PET) scans of sections through a healthy brain (left) and a schizophrenic brain (right). The colours show different levels of activity within the brain during an attention test. Red shows high activity, through yellow and green to black (very low activity). The schizophrenic brain shows much lower activity in the frontal lobes.

MIND THE GAP

Humans have an uncanny ability to put themselves in the position of others.

Young children can be horribly selfish. They want things for themselves and are not interested in sharing. Partly this is because they lack the ability to appreciate what other individuals are thinking and feeling. This develops gradually during childhood.

Being able to understand the feelings and motivations of others, being able to put yourself in other people's shoes, is known as theory of mind. It is the basis of what we know as empathy – appreciating what others are feeling and how our own behaviour may impact on them.

It is likely that people's capacity for empathy varies. We can probably identify people whom we feel are particularly empathic (or seem to lack it).

In some conditions, theory of mind seems to be very badly affected. A common feature of autism, for example, is an inability to appreciate what others are thinking and feeling, or to appreciate the impact of one's actions on others. As a result, people with autism generally lack social skills, and have to be taught how to behave in social situations where most of us would behave naturally, relying on unconscious social skills.

Body talk

When people scratch their nose, does it mean they are lying?

Popular psychology is full of accounts of 'body language'. If I cross my arms, I'm being defensive; if I pull my ear, I'm likely to be lying; if I avoid your gaze, I've got something to hide.

The basis of body language was in animal communication. Without language, animals need ways to convey information to one another – and use parts of their bodies in imaginative ways to do so. Faces are again important, but so too are, for example, gestures of submission. Mating relies heavily on signals of intent, receptivity or rejection, often leading to elaborate rituals.

The popularity of studying body language in humans owes much to **Desmond Morris**. He argued that information from animals could be extrapolated to humans. The scientific value of this area, social anthropology, has been questioned by many neuroscientists.

The neuroscience of body language has been studied much less well than responses to faces. But it does appear that the brain can recognise particular **body postures** and that recognition occurs early during processing of a scene (as is also true of face recognition). There could be brain modules specifically for body perception.

The body language responses studied to date seem to be closely linked to the brain's **emotional responses**. So seeing someone showing signs of distress fires up our amygdala. This cues behaviour needed to escape from threatening stimuli (such as the need to run away very fast).

We also seem to be particularly sensitive to bodies in **motion** – though as artists through the century have proved, our emotional responses to still images of bodies in peril are powerful and quick to appear.

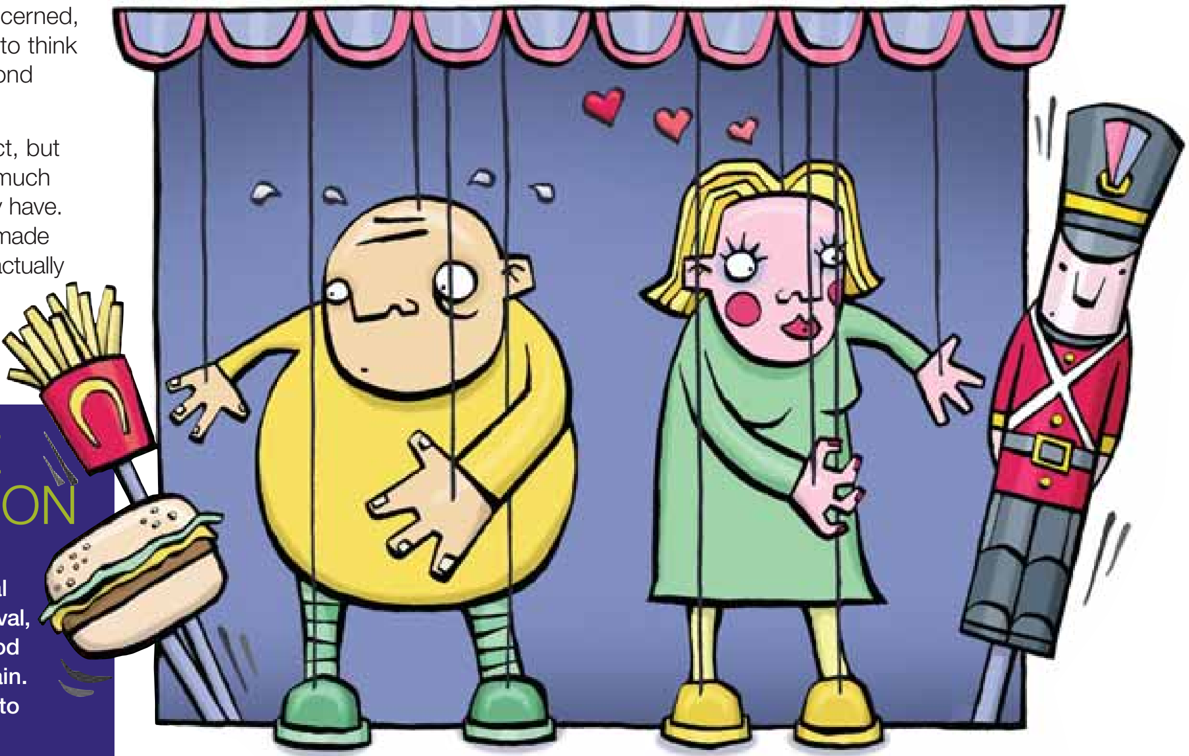
BODY LANGUAGE: Faces reveal much about someone's inner thoughts and feelings. We also subconsciously draw some information from body posture. What might these people be thinking or feeling?

WHY DO I DO WHAT I DO?

We usually like to believe that we are free agents, capable of informed choice about what we do.

Where naughty treats are concerned, though, we find it convenient to think we are driven by powers beyond our control.

Both points of view are correct, but it is not always obvious how much **conscious control** we actually have. Even when we think we have made a conscious choice, this may actually be an **illusion**…



THE CYCLE OF ADDICTION

Eating and taking part in sexual activity are essential for life and for species survival, so are rewarded with a good feeling produced in the brain. Repeating the tasks leads to a cycle of reward.

Dopamine, a feel-good chemical messenger (neurotransmitter), is central to this cycle. Alcohol, nicotine, and drugs such as cocaine and heroin all increase dopamine levels.

But why do some substances just produce pleasure while others are addictive? The likely answer is that in addiction, substances trigger permanent changes to the dopamine/reward pathways, which lead to cravings. In effect, drug intake goes from being a voluntary activity, under conscious control, to an unconsciously driven desire, with different brain areas taking over.

Pinpointing exactly how each substance works can help identify ways to block the addiction cycle.

Wired

How much of our behaviour is fixed, embedded in the neural networks of our brain? Is it 'hard-wired' – set for life – or more flexibly arranged?

Behaviour is complex. No single gene encodes for it, nor does any single event or experience control it. Although we can control some aspects with our own willpower or **volition**, in the end our behaviour arises from an intricate interplay between our environment, our genes and us.

OUR GENES EVEN HAVE SOME CONTROL OVER BEHAVIOURS THAT WE ARE UNAWARE OF.

Science has shown that many patterns of behaviour, including alcoholism, criminality and homosexuality, have some **genetic influence**. Our genes even have some control over behaviours that we are unaware of – such as hand clasping (people tend to intertwine clasped hands with either the right or the left side uppermost).

In the case of alcoholism, **genes** may code for certain receptors that bind chemical messengers in the brain, or for enzymes involved in breaking down alcohol. Our **social and cultural upbringing** may also affect our alcohol consumption – our parents may be teetotal, for example.

There is bound to be **interplay** between these factors. We may be born with a genetic predisposition to alcoholism but lucky enough in our family and social life that we never get tipped over the edge into dependency.

Also, the brain itself is not set in stone. It develops through childhood, goes through massive change at **adolescence**, and reaches maturity in our early 20s. Even then the brain retains significant plasticity – it learns and adapts. So if we practise tennis we get better at it.

So exactly how much of our behaviour can be modified, and how much is inborn or fixed by our upbringing? It is hard to say. With humans such a debate is risky, as the notion of '**hard-wiring**' can be used to support racist or sexist views or other forms of bigotry. On the other hand, in Steven Pinker's famous phrase, we are clearly not '**blank slates**' either.

FAST FACT

Our brains form a million new connections every second of our lives

A BRIEF HISTORY OF MENTAL ILLNESS

Pre-history (e.g. Stone Age)
Trepanning (drilling holes in the skull) is used to get rid of evil spirits.

Approx. 400 BCE
Hippocrates treats mental illness as a problem of the body rather than a punishment sent by the Gods.

1377
Opening of The Bethlem Royal Hospital in London, also known as Bedlam.

1600s
Chains, shackles and imprisonment are largely used to restrain and control the mentally ill.

1850s
Asylums built.

1870s
Normal ovaries are removed to treat 'mental madness' and 'hysterical vomiting' in some women.

Early 1900s
Psychoanalysis inspired by Sigmund Freud, Carl Jung and others.

1911
Swiss psychiatrist Eugen Bleuler first uses the term 'schizophrenia'.

WWI
Patients with shell shock are counselled – the precursor of modern treatment for post-traumatic stress disorder.

1936
Lobotomy (surgical removal of part of the brain).

1938
Electro-shock therapy for schizophrenia and manic depression.

1949
Lithium for psychosis and manic depression (now called bipolar disorder).

1952
The first anti-psychotic drug, Thorazine, for psychosis.

Mid-1950s
Behaviour therapy for phobias.

1960–63
Librium and Valium for nonpsychotic anxiety.

1970s–1980s
A move away from asylums, mental institutions and hospitals to community-based healthcare.

1980s
'Selective serotonin re-uptake inhibitors' for depression.

1990s
New generation of anti-psychotic drugs for schizophrenia.

Morality tales

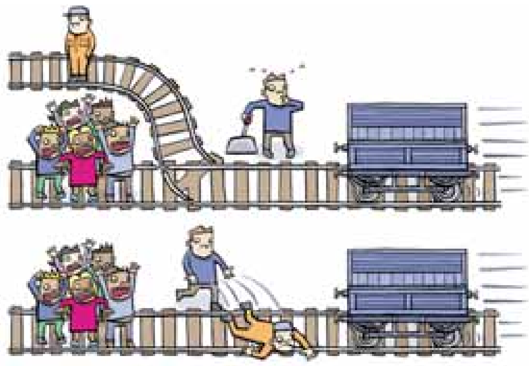
Morality is a social sense of what is right or wrong. One of the most hotly contested questions is whether our brains come with some sense of morality already built in or whether it is something we have to learn.

Our morals differ according to our sex, religion and culture. They also change with age. Very young children can't tell right from wrong. In toddlers, morality is based around themselves. With age, morality shifts towards **peer-group values** and eventually moves towards consideration of the wider social group.

Morality is, of course, deeply rooted in the values held collectively by society. Philosophers and theologians have debated for centuries whether **absolute moral values** exist, or whether they are reflections of what is socially acceptable. What was morally acceptable to the ancient Greeks – slavery, for example – may not be seen as OK today.

Neuroscience is helping us to understand the biological basis of human morality. Examination of people with **brain lesions** (damage) shows that people with early damage to the **prefrontal cortex** do not develop normal moral responses. They lie and cheat without feeling guilt or regret. Brain scans of people with **antisocial personality disorders** show that psychopaths have less grey matter in the prefrontal cortex than normal people.

Functional imaging has shown that the **superior temporal sulcus**, as well as the prefrontal cortex, is involved in making moral judgements. **Psychological tests** can also be used to see how people respond to moral dilemmas, or questionnaires examining their moral reasoning (i.e. how they would respond in different situations). These again show that people with personality disorders are less able to identify the morally most appropriate courses of action.



A classic morality study is the 'trolley problem'. You are presented with a dilemma: a runaway trolley is about to kill five people. Should you throw a switch to divert the trolley onto a spur on which it will kill one person and allow the five to survive? You are then given the same scenario, without the spur but with the option to throw a man on the track to save the five. Should you throw him? People usually say 'yes' to the first dilemma, and 'no' to the second. Interestingly, fMRI studies show that different parts of the brain are active as the subject considers the two scenarios.

Strange behaviour

Many conditions with a genetic link affect the brain or behaviour – including autism, schizophrenia and bipolar disorder (manic depression). There are a wide range of disorders, however, showing distinctive alterations in behaviour (including the examples below). Studies of people with these disorders can shed light on brain function.

REFLEX: Tim Howard, goalkeeper for Manchester United and the USA, has Tourette syndrome.
Rex Features

Tourette syndrome

- People with Tourette have characteristic, semi-involuntary tics such as sudden, rapid movements (e.g. blinking or sniffing) and verbal tics (e.g. shouting or swearing).
- People seem unable to suppress unconscious thoughts or reflex-driven movement, possibly due to disrupted communication between the prefrontal cortex and other areas of the brain.
- Recent research has shown that a gene called *SLITRK1* that is involved in brain development is disrupted in a small number of cases.

FRIENDLY FACE: A young girl with the typical appearance of Williams–Beuren syndrome.
The University of Utah, Genetic Science Learning Center

Williams–Beuren syndrome (Williams syndrome)

- Children with Williams–Beuren syndrome have a characteristic elfin-like face, and tend to have a degree of developmental delays and some learning disorders.
- They frequently have a love of music and are polite and friendly by nature, often being overly trusting of strangers.
- Recent research suggests the syndrome is caused by loss of a chunk of chromosome 7, which typically removes 28 genes.

REAL VOICES

The brain works in mysterious ways. Some people experience life in very different ways because of quirks in the way their brain operates. We spoke to two such people about the impact of unusual brain function – **synaesthesia and schizophrenia** – on their lives.

SYNAESTHESIA is an unusual condition affecting the senses. Typically two senses become mixed – for example, sounds give rise to a visual experience, or sight is linked to touch sensations (someone with vision–touch synaesthesia feels a touch if they see someone else being touched). Its causes are unknown, but a genetic contribution is possible. The symptoms may stem from cross-wiring in the brain, so that nerve impulses triggered by one sense activate brain areas responsible for a different sense.

SCHIZOPHRENIA is typified by unusual ways of thinking; common symptoms include hallucinations or internal voices, delusions and paranoia. Symptoms vary significantly, however, and the condition overlaps with bipolar disorder (manic depression). It tends to emerge in late adolescence. Its origins are uncertain; genetic and environmental risk factors (e.g. poor maternal nutrition) have been identified. Roughly translated, schizophrenia means ‘shattered mind’; contrary to popular perceptions, however, it is not associated with multiple personalities.

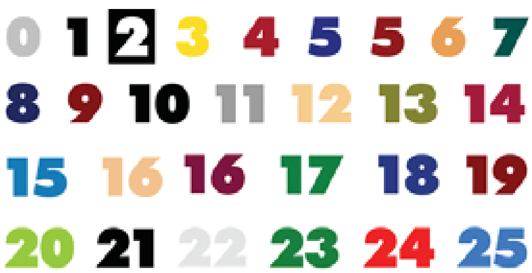
Julie Roxburgh is a retired music teacher. When she hears sounds she sees them as colours: a condition known as sound-to-colour synaesthesia.

What are the most significant features of your synaesthesia?

JR It is very hard to describe. It’s as if I have a big screen in front of me, and when I hear sounds they appear on the screen as colours and shapes. Sometimes they are moving and they appear in different areas of the screen every time. I am a trained musician and I used to teach oboe and clarinet, so I know what colour to expect when I hear different instruments. The low notes on a clarinet, for example, are a blue-black colour and the high notes are a murky white. Other sounds, such as traffic, can appear differently every time.

How does it affect your life?

JR I can’t always differentiate between my senses – whether I am hearing something or seeing it. When my alarm clock rings, I see brass-coloured bubbles and white lines. It’s quite disturbing first thing in the morning when you are waking up. Seeing colours and shapes all the time muddles up my thought process, especially when I am tired.



RIGHT
One person’s view of numbers, which are associated with particular colours.

WHAT ROLE DO YOU THINK YOUR BRAIN HAS IN YOUR CONDITION?

JR It could have something to do with the connections in your brain – the wiring as you might call it. I know I certainly don’t have any control over it.

Do you consider your condition an illness or a disability?

JR I don’t think it could be called a disability compared to the dreadful problems that other people have. However, it does create difficulties. Society is not designed for synaesthetes. I can’t go to places where there is a lot of noise. Music in shops is so distracting.

How do people react when you tell them about your condition?

JR Most people find it hard to understand. Describing it is like trying to explain colour to someone who has been blind from birth. Equally, I can’t think what it would be like not to be synaesthetic. My husband is a composer and I can’t imagine how he hears in his head the sounds he wants to write down, yet doesn’t see them.

What do you think the origins of your condition are?

JR My brother, my mother and my son are all synaesthetic and I think my granddaughter might be. So there could be a genetic link.

WHAT ROLE DO YOU THINK YOUR BRAIN HAS IN YOUR CONDITION?

EJ There seems to be a tendency to release too much or not enough of certain chemicals from time to time. You start feeling anxious and get very powerful emotional charges. As time goes by you begin to recognise the occasions when you need to do something about it, such as talk to your psychotherapist.

DO YOU FEEL COMFORTABLE TELLING PEOPLE ABOUT YOUR CONDITION?

EJ Yes, and I believe it is important to speak out. There are many people suffering in silence because of ignorance and prejudice. More people like myself need to tell others what it's like.

ABOVE: Composite artwork (by Chris Nurse) in two halves illustrating the decline into mental illness and the shattering of normal perception.

Edward Jones, 58, is a volunteer with the mental health charity Rethink. He was diagnosed with schizophrenia at the age of 21.

What are the most significant features of your condition?

Edward Jones Anxiety, paranoia and depression are features. But on a day-to-day basis delusions are the biggest problem I have to deal with. My condition distorts perception so I make sure to keep talking to people and asking them what's real and what's not. In very severe cases of schizophrenia you can't actually make the distinction.

How does it affect your life?

EJ I sometimes feel anxious and depressed. I go over and over what people have said to me and put a negative interpretation on it. However, experience has shown me that these feelings won't last forever and that I just have to wait for them to pass.

What treatment have you had?

EJ The psychiatrist I saw after I was first diagnosed saved my life. He was able to gain my trust and I felt able to tell him exactly how I was feeling. Now I see a psychotherapist whenever I feel the need to talk to someone.

How do you feel people with schizophrenia are portrayed in the media?

EJ When a person with schizophrenia commits a violent crime the media tends to give it so much attention. But as far as I know, the statistics show that fewer people with schizophrenia commit crime than ordinary people. In a way, I don't really blame the media for this because a lot of people like me aren't speaking out.

What do you think the origins of your condition are?

EJ I'd say the causes are genetic. My mother had schizophrenia. She twisted everything you said to make it seem hostile. She became angry very quickly and thought she heard voices.

Are you responsible?

ONLINE ACTIVITY

It was a high-profile murder case…

The accused had brutally slain a colleague…

His defence? He'd been suffering from a brain tumour at the time, the physical changes in his brain causing him to become more aggressive and impulsive, making him less responsible for his actions.

The press had a field day…

This issue's classroom activity is based around two podcasts. They are news reports of the court case – produced in completely different styles.

What do you think?
In this activity, students are encouraged to think about the brain works, how it controls behaviour and whether we are always fully responsible for our actions. Using specially commissioned podcasts, students can also consider how science is reported in the media.

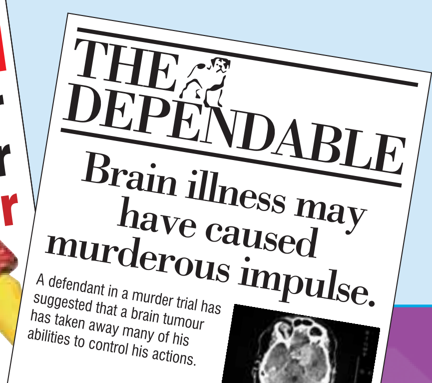
The activity is supported by background material, including the two podcasts – which can be listened to on the website or downloaded onto an MP3 player – plus support notes for pupils and teachers.

Full details can be found at **www.wellcome.ac.uk/bigpicture/thinking**

THE Sham

'Zombie' killer blames cancer for axe murder

A 35-year-old man has claimed his brain cancer turned him into a murderer. The savage attack shocked local residents, when formerly mild-mannered Peter Jones turned into an axe-wielding maniac. Now he says it's all the fault of his cancer.



THE DEPENDABLE

Brain illness may have caused murderous impulse.

A defendant in a murder trial has suggested that a brain tumour has taken away many of his abilities to control his actions.

WHAT DOES IT ALL MEAN?

We are rapidly gaining a much better understanding of the brain and how it operates. We are beginning to see how our thought processes and actions are shaped by activity in the brain.

This new knowledge is exciting, but presents us with many **challenges**. And tools and therapies for use in medicine or research could equally well be applied **socially** for other uses. How are we going to manage these ethical quandaries?

Responsible adults?

If a lot of our behaviour is outside our conscious control (or feels as if it is), can we always be held responsible for our actions?

Our legal system (and many other aspects of society) are based on the idea that we are '**free agents**', able to decide for ourselves how we behave.

But how much freedom do we actually have to control our behaviour? Some brain responses are not under conscious control. Sometimes, even when we think we are making a conscious decision, our brain has already made an unconscious one. Or our conscious and unconscious wrestle for control of our actions.

Our **genetic inheritance** will affect our brain and behaviour, as will the environment we experience in the **womb**, and the way we are **brought up**. By the time we are adults, our scope to behave in any way we choose is significantly reduced.

On the other hand, **genetic or neuroscientific determinism** – that we are 'born' or 'hard-wired' to behave in a particular way – can become a self-fulfilling prophecy. The prefrontal cortex, the 'thinking brain', still has plenty of scope to shape our actions.

Legally, courts are more lenient if a defendant can prove '**diminished responsibility**'. Sentencing will also depend to some extent on an assessment of a defendant's mental health. So far, there has been little evidence that judges are willing to consider **biological susceptibilities** as a justifiable defence. As we discover more about the links between brain and behaviour, it is likely that this will become a more common issue.

YOU ARE THE JUDGE

CASE STUDY 1

Defendant X

- Impulsive behaviour runs in his family.
- He has a variant in a neurotransmitter receptor gene that may influence behaviour.
- He hit a bouncer at a nightclub, causing actual bodily harm.

Do any of the factors influence whether he is found guilty or not? Should any influence the punishment if he is found guilty? Should any biological factor ever be considered?

CASE STUDY 2

Defendant Y

- She was brought up on a deprived inner city estate.
- She was physically abused as a child.
- She stole a mobile phone to give to her boyfriend.

Do any of the factors influence whether she is found guilty or not? Should any influence the punishment if she is found guilty?

HAVE YOUR SAY...

On the *Big Picture* website you can cast your vote and see how your answers compare to everyone else's.

Hands off my brain

Should the contents of the brain be 'private property'?

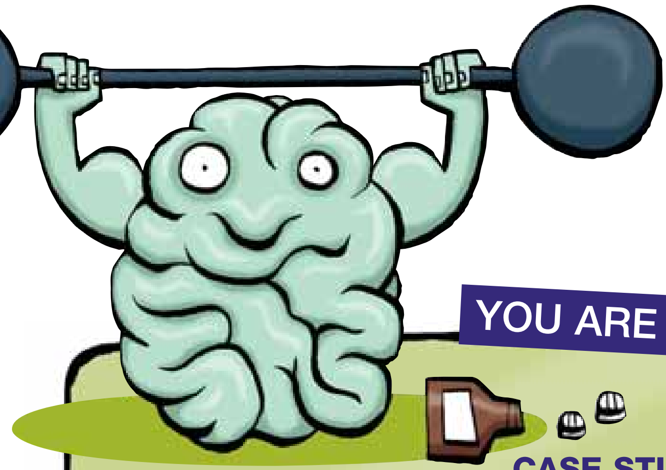
We sometimes go to extreme lengths to prevent people knowing what we are thinking. The most successful poker players have deadpan faces, so other players do not know what kind of hand they have. Or, in everyday life, we might tell the odd little **white lie**, or not tell someone what we really think about them if we want them to help us.

But suppose our real, inner thoughts could be laid bare. Functional imaging provides a powerful view of our **inner thought processes**, revealing things that our outer expression may be hiding.

It has revealed that people respond differently to black faces than they do to white faces – evidence of hidden racial prejudice? And there is considerable interest in using such tools to spot when people are **lying**. There are characteristic patterns of brain activity that light up when people are not telling the truth (though brain scanners are not 100 per cent accurate as lie detectors at the moment).

This may be seen as intrusive. In the USA, the Center for Cognitive Liberty and Ethics argues: "What and how you think should be private unless you choose to share it."

Supporters say that brain scanning could have great use – identifying potential paedophiles seeking to work in schools, or helping the police solve crimes. On the other hand, even if they were infallible (and they are not) the meaning of scanning results is open to interpretation. We have instinctive responses but that does not mean we always act on them.



YOU ARE THE PARENT

CASE STUDY 3

Your son wants a 'cognitive detector' chip implanted in his temple so he can interact better with his immersive virtual reality computer game.

Do you let him have the implant? What if it aided learning as well as gaming? Is there any reason to limit the use of such technologies?

CASE STUDY 4

You find packets of modafinil, a memory-enhancing drug, in your daughter's bedroom. She says she needs them for her exams – everyone else is using them, and she'll be at a disadvantage without them.

Would you allow her to take them? Should people be free to use enhancing drugs or technologies? What limits, if any, should be placed on their use?

Better brains?

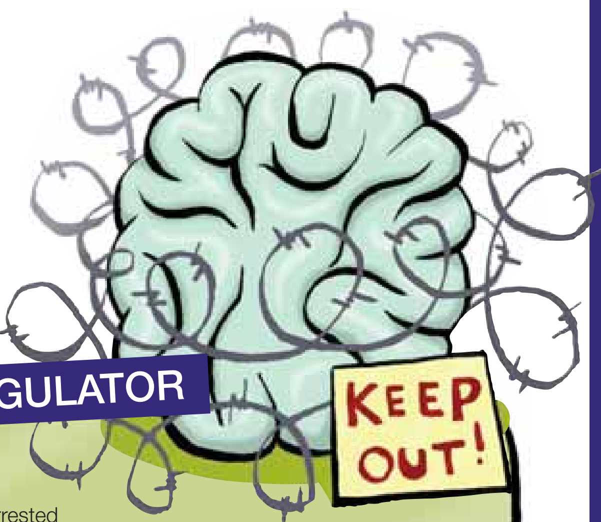
How should we react to the potential to enhance our brain's abilities?

New drugs are appearing that act on the brain. Initially developed to tackle medical problems, they also have the potential to be used by the healthy to enhance brain function.

A good example are the '**cognitive enhancers**'. Developed to protect against memory loss in Alzheimer's disease, they can also boost normal memory.

Some people fear we are heading towards becoming '**super-humans**', with everyone feeling pressured to enhance themselves or their children for fear of falling behind in a competitive world. The gaps between the haves and have-nots could widen. And what does it all mean for our view of what it is to be human? We all have our flaws – are we chasing an impossible dream of perfection?

On the other hand, the whole point of learning is to expand the mind, and we think nothing of providing extra school or educational activities, or pump children full of vitamins to boost their IQ. And we use drugs like **caffeine** all the time to boost mental performance. What is so different about pharmacological approaches, if tried and tested?



YOU ARE THE REGULATOR

CASE STUDY 5

Shifty Sam Fencer has been arrested by the police searching for missing bullion. He denies everything. They are convinced he is lying and would like to do a brain scan to prove it.

Should the police be allowed to scan Sam's brain? Would it make a difference if a child were missing rather than bullion? Should there be any limits on how the police use brain scans to solve crimes?

CASE STUDY 6

Giselle Megabucks, a top R&B singer and noted celebrity, wants to scan her boyfriend's brain to check that he really loves her.

Should she be allowed to? If he agrees, is there any reason to refuse? Should any limits be placed on the use of such scans?

DESCARTES REVISITED

The rich and fascinating internal life we experience is being reduced to the product of electrical activity. Does this diminish our view of humanity?

Descartes's idea that the mind and body are distinct (see page 6) has been hugely influential. Partly it is because it is such an appealing notion – our sense of self is primarily a mental construct, based on our thoughts and personality, albeit one influenced by our physical form.

The consequences of this division run very deep. So some groups will focus on the mind, in a holistic 'whole-body' sense. The exact nature of the 'mind' is less important than whether it is healthy, fulfilled and so on. How do collections of minds interact socially? Psychologists would come at the brain from this direction, and it is the basis of psychological therapies such as cognitive behavioural therapy.

Over the past few decades, though, research has become increasingly dominated by a 'reductionist' approach, which seeks to break down complex biological phenomena into smaller pieces that can be analysed and understood.

This approach argues that the mind, whatever it is, is the product of the coordinated activities of brain cells. If we knew how neurons worked, individually and collectively, we would understand how conscious experience came about. This is the goal of neuroscientists, and the basis of pharmacological treatments of brain disorders, which manipulate brain chemistry to change mood or behaviour.

Although the models are not incompatible, there is a tendency for groups of researchers to work independently of one another. However, answers to the most interesting questions will probably combine both approaches – how does cognitive behavioural therapy affect brain biochemistry? What is the neuroscientific basis of the placebo effect? What cognitive processes underpin social communication?

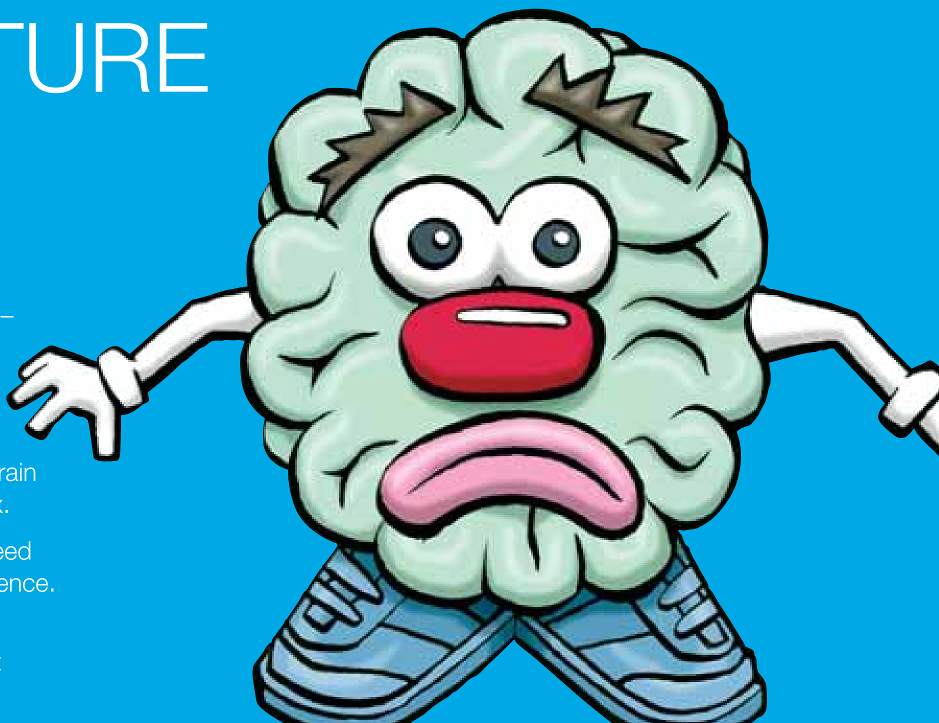
Understanding humans

It is no longer a fanciful thought that one day we will be able to understand, in entirety and in a scientifically robust manner, all human experience. We still have a long way to go, but even the prospect of that understanding raises intriguing questions.

Some may find this conclusion hard to swallow, finding it difficult to accept that science can 'explain' the mysteries of love or morality. Or they may feel that it diminishes human dignity to think of the mind as an excitable neural network.

On the other hand, scientists would point to the extraordinary beauty apparent in the awe-inspiring complexity of the human brain, shaped by four billion years of evolution. Far from diminishing our sense of wonder, it enhances it further.

THINKING:
THE BIG PICTURE



- New tools such as functional imaging are enabling us to study **brain activity in living people**.
- Different areas of the brain tend to be **specialised** for different tasks.
- Different specialist areas do not act independently – there is much **communication** between them.
- The front part of the cortex is where most of our **reasoning** takes place.
- **Consciousness** seems to reflect linked areas of brain activity across different parts of the cerebral cortex.
- **Neural activity** in a region of the brain has to exceed a **threshold** before it registers in conscious experience.
- Our **senses** capture information about the outside world, but they can be fooled, and they operate at both conscious and subconscious levels.
- Our **behaviour** results from a **combination** of unconscious reaction and conscious thought.
- Our behaviour also depends on factors such as **mood**, **personality**, **memories** and **feelings**.
- Although the **overall structure** of the brain does not change, the strength of connections between neurons can change, giving the brain significant **plasticity**.
- The factors shaping behaviour include **genetic** and **environmental** influences, which can influence the wiring of the brain.
- A better understanding of the roots of human behaviour is posing challenging **legal** and **social** questions.

BIG PICTURE SUBSCRIPTIONS

Individual copies of each issue in the *Big Picture* series are available free for teachers and other education professionals, or anyone with a professional interest in the topic.

To order an individual copy of a specific issue, or subscribe to receive a copy of each issue in the series, sign up at **www.wellcome.ac.uk/bigpicture/order**

Additionally, teachers can order a class set of two copies or more for students.

Order sets of a specific issue or subscribe to receive copies of each issue until further notice.

Class-set prices
2–20 copies: £1.00 per copy per issue (inc. P&P in the UK)
>20 copies: £0.75 per copy per issue (inc. P&P in the UK)

Postage and packing charges
UK – free of charge
EU – £0.15 extra per copy ordered
Rest of world – £0.30 extra per copy ordered

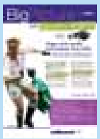
Other interested groups can also order copies at these prices.

Payment methods
We accept cheques, and all major credit cards and debit cards.

Contact
See www.wellcome.ac.uk/bigpicture for full details, or:
T +44 (0)20 7611 8651
E publishing@wellcome.ac.uk

Or write to:
Big Picture series
The Wellcome Trust
FREEPOST
ANG 6754
Ely CB7 4YE

Previous issue



January 2006:
Big Picture on Sex and Gender

www.wellcome.ac.uk/bigpicture/sex

Order 10 or more copies and receive a free poster on weight control and obesity.

Next issue
January 2007: Evolution

FEEDBACK
If you have any comments on the *Big Picture* series, please email bigpicture@wellcome.ac.uk.