Richard M. Restak

Mind

The Big Questions

THE BIG QUESTIONS

Mind

Richard M. Restak

SERIES EDITOR
Simon Blackburn

Quercus

Quercus

New York • London

Design and illustrations in *How do Brains Come to Exist?* by Patrick Nugent

e-ISBN 978-1-62365-497-9

Distributed in the United States and Canada by Random House Publisher Services
c/o Random House, 1745 Broadway
New York, NY 10019

www.quercus.com

THE BIG QUESTIONS

Mind

Richard M. Restak is a practising neurologist and former president of the American Neuropsychiatri Association.

Author of nearly 20 books, including several *New York Times* bestsellers, he has received widesprea acclaim for his incisive and accessible treatment of this complex topic. He is currently Clinical Professor of Neurology at George Washington Hospital University, and maintains a private practice in neurology and neuropsychiatry in Washington, DC.

The Big Questions confronts the fundamental problems of science and philosophy that have perplexe enquiring minds throughout history, and provides and explains the answers of our greatest thinkers. This ambitious series is a unique, accessible and concise distillation of humanity's best ideas.

Series editor **Simon Blackburn** is Professor of Philosophy at the University of Cambridge, Researc Professor of Philosophy at the University of North Carolina and one of the most distinguished philosophers of our day.

Titles in *The Big Questions* series include:

PHILOSOPHY
PHYSICS
THE UNIVERSE
MATHEMATICS
GOD
EVOLUTION
MIND
ETHICS

Contents

INTRODUCTION

The mind – what it is, how it works – has long exerted a fascination, and dedicated thinkers since the early philosophers have wracked their brains over it. In fact, therein lies an enduring Big Question. Is the brain the same as the mind? And following on from that, if we cannot look at our mind or our brain without employing them as instruments of our exploration – do we risk invalidating our investigation? The paradox of ‘self-reference’ hovers over attempts to understand the mind.

There are other ways of formulating this paradox, but at the core of it is a question about identity, sense of an ‘I’. In the history of thought, the mind has, along with the brain and the soul, formed a triad of ways to understand the essence of a person. Once of vital importance to philosophers, the sou is now largely the province of theology and religion; the brain, by contrast, has entered common parlance comparatively recently, while ‘mind’ endures in both everyday language (‘keep it in mind’, ‘mind your manners’, ‘he’s losing his mind’) and remains suggestive of higher purposes – reflection intellect, imagination. Philosophers and anatomists – witness Descartes or Leonardo da Vinci – could if not always accurately, attempt to delineate connections between motor functions, the senses and th brain. On the other hand, there is not much poetry associated with the brain – and a very great deal with the mind.

Today, with the advance of science, the brain edges into the limelight, its status enhanced as new discoveries about its structures and operations emerge. Computer science suggests a metaphor, whereby the brain may be the hardware and the mind its software. Reducing the metaphor to its simplest form produces an equation: mind = all the things a brain does.

While I too have made such claims in several of my earlier books, I’m now less certain of that equivalence. For one thing, the word ‘mind’ can be a collective attitude or Zeitgeist, as in ‘the mind o a nation’. Further insights into this mind-writ-large view have been achieved thanks to technology. The Internet now makes it possible to gather real-time data on the activity patterns and verbal and written expressions of millions of people, confirming that a person may have a different mind to say or do something when part of a group than when in isolation. This is one of the reasons behavioural predictions, about individuals or groups, are so difficult to make. Sometimes collective actions – both positive and negative – may be unimaginable to the individual minds comprising the group. It is difficult to account for this solely in terms of brain activity and neuroscience in its present form.

In addressing Big Questions about the mind, the sense of self-referentiality is never far from the surface. We cannot ask ‘What is thinking?’ without thinking about it. We cannot ponder ‘What is knowledge’ without reflecting on the thought processes that we use in order to acquire much of our knowledge. However, in tackling such questions there is a choice: whether to regard it as primarily a philosophical enquiry, or whether it is a scientific enquiry. My approach is to tend towards the latter. In the 21st century few would argue that memories and emotions, words and ideas, dreams and imagination, perceptions and thoughts, and a sense of self and of the outside world are not activities o the brain. We often recognise this most clearly in their absence, by what we see when there are interferences with the normal workings of the brain. And today we are not simply relying on our own self-referring minds to consider these issues – brain imaging, cognitive studies, precise anatomical studies, chemistry and many other investigative modes are playing a role. To put it another way, while, philosophically, the ‘self-referential’ paradox remains, there are practical ways in which we ca step outside of ourselves to help tackle the Big Questions.

In approaching the questions posed in the chapters that follow, I have not aimed at definitive ~~answers; in many instances there are no single answers. I have sometimes taken an author's privi~~lege of emphasizing answers that I personally favour, but in doing so I don't expect that my responses will meet with universal agreement. My purpose is to entice the reader to assume an active role in exploring and thinking – to use my responses as a spur to coming up with their own responses to the 20 Big Questions. If I've achieved my purpose, readers will be persuaded to assume the role of good jurors who, after examining the evidence, reach their own conclusions, while retaining full awareness that other people might come to different conclusions.

Richard Restak
Washington, DC, USA
Morell, Prince Edward Island, Canada

CAN WE HAVE A MIND WITHOUT A BODY?

Are we creatures of pure thought?

Think back to the last time you had a bad case of flu. Alongside the fever and aching body, you weren able to think very clearly, were you? If you tried to read a book or do any work you couldn't concentrate on it. In such a state, you would be unlikely to believe that the mind can be considered separate from the body – the flu was affecting both your mind and your body.

Neuroscientists speak of 'embodied cognition' as a shorthand for the linkage of all aspects of our mental lives to our bodily experiences. The ancients had an inkling of this mind–body dependence. They postulated different personality types based on the prevailing influence of the four physical elements of air, fire, earth and water and their respective qualities of dryness, warmth, cold and moisture. Later theories associated air, fire, earth and water with yellow bile, blood, phlegm and blac bile. Diseases were believed to be due to an imbalance of one or more of these four bodily 'humours' with humoral theory inspiring one of the earliest methods for personality assessment. We still emplo humoral terms in describing people's personalities. Short-tempered people are 'choleric', pessimisti types 'bilious', confident individuals 'sanguine' and apathetic folk 'phlegmatic'.

Although personality assessment has come a long way since the Greeks, the path has not been smooth. From the 17th century onwards, Cartesianism (more about that in a moment) held out for the belief that the mind existed apart from the body. (Apparently Descartes never suffered a case of the flu.) However, by the 19th and early 20th centuries psychologists such as William James linked personality and emotions with bodily states. James suggested that emotions arose from a person's perception of physical changes in the various internal organs: stomach contractions, heart and breathing rates, the dilation and contraction of blood vessels – in other words, those bodily changes mediated by the autonomic nervous system. James went even further and maintained that our mental states were the consequences of these bodily changes: 'We feel sorry because we cry … not that we cry … because we are sorry.'

Bodily illusions

Recently neuroscientists have elaborated on James's emphasis on how our bodily states can influenc our mind, especially our thoughts and behaviour. They've found that people differ from each other a good deal when it comes to their awareness of their bodily states.

Here's a quick test you can use that will give you some insight into your own bodily awareness. Have a friend take your pulse over the course of one minute. While they're doing that silently estima your heart rate. Compare your estimation with the actual measured heart rate. About a quarter of people engaging in this exercise will achieve an accuracy of at least 80 per cent. Another quarter, in contrast, will be off by 50 per cent or more. Intriguingly, those who do well on the test are less susceptible to what neuroscientists refer to as 'embodiment illusions'.

One such illusion is the face-swap illusion, where a person is stroked on the face while he is lookin at a screen showing a face other than his own being stroked in at the same time. The synchronous tactile stimulation of his own face and the face on the monitor increases the likelihood that the perso will believe that the image on the screen is his own. This simple experiment of neuroscientist Manos Tsakiris provides evidence that sensory inputs can alter our mental representations of ourselves, such as face recognition, as well as our sense of ownership of our body's components.

This fluidity in body perception actually influences how we see the world around us. In another experiment from the Karolinska Institute in Stockholm volunteers were tricked into full-body illusions in which they experienced ownership of a small doll's body or a giant's body. This change i the size of the experienced body from a small one to a large one resulted in consistent changes in the perception of the world: it appeared larger in the case of the doll illusion, and smaller in the case of the giant illusion.

Body-swap illusions emphasize the significant influence that our bodily sensations exert on what our brains perceive. (See *How Do We Make Sense of Sensation?*)

Body movement and the mind

In all of the examples described so far, mind, sensation and bodily movement are intertwined. Bodily movement is especially important as a direct expression of the mind. Movement can be immediate and subconsciously generated, such as the automatic movements of my legs as I walked across the room a few moments ago with no specific intention in mind. Or it can be based on will and conscious intention, such as when I decide (as I did a moment later) to contact my travel agent to book a flight.

Automatic bodily movements such as walking across a room are largely under the control of areas beneath the cerebral cortex (the subcortical nuclei and circuits, as neuroscientists refer to them). The cerebral cortex plays little part and this makes sense since we don't consciously plan or concentrate o the movements of our legs except under special circumstances, for instance, learning to dance.

In contrast, deliberate actions such as calling a travel agent to book a flight require some degree of conscious intention associated with activation of the prefrontal and frontal areas of the cerebral corte where the intention originates. Once an intention is formulated, it is conveyed to the premotor area o the cerebral cortex, which formulates the motor programme for motion. Finally, the motor programm is conveyed to the motor areas, which communicate with the muscles carrying out the movement.

However, the presence of movement doesn't necessarily imply a mind. Mechanical devices routinely carry out movements that if done by a person would require acts of mind. Take, for exampl sliding automatic doors, which have been around since 1954. Minds aren't involved beyond the design, construction, installation and maintenance of the door.

More recent and more mind-like since they involve more than just movement are some of the currently available mobile phone apps that can identify such things as landmarks, barcodes, wine labels, textbooks and DVD covers. One app identifies works of art based on a database of more than a million paintings.

The body isn't completely eliminated, of course. Somebody has to activate, read and interpret the information provided by these apps. Rather than representing a mind operating without a body we have in these examples a weakening of the links between mind and body: a technologically created *disembodiment*.

Disembodied minds

We encounter the mind existing in the absence of body movement in *locked-in syndrome*. In this unfortunate state the patient is aware, awake and cognitively intact but cannot move or verbally communicate because of paralysis of all of the voluntary muscles of the body with the exception of the eyes. In the extreme version of this horrifying condition, *total locked-in syndrome*, the eyes are paralysed too. The condition was vividly described by French journalist Jean-Dominique Bauby, who suffered a stroke in 1995. When he came out of a coma three weeks later he was paralysed, with the exception of his left eyelid, the movement of which he retained the ability to control. Over time he developed a system of communication by blinking this eye and he succeeded in 'dictating' a memoir of his experiences, *The Diving Bell and the Butterfly*, later made into a 2007 film.

Another fictional example of locked-in syndrome is the character Monsieur Noirtier de Villefort in Alexandre Dumas's novel *The Count of Monte Cristo*. Dumas describes him as a 'corpse with living eyes' who communicates his thoughts via eye movements and facial expressions. Monsieur de Villefort forms sentences by indicating with his eye movements the letters and words that he wants a his grand-daughter recites the alphabet and scans dictionary pages with her finger.

While *locked-in syndrome* allows for some minimal linkage between mind and body, in other neurologic conditions, such as *minimally conscious state* (*MCS*) and *coma vigil*, the retention of mental powers was, until recently, more controversial since the patient can't communicate with others. But recent fMRI (functional magnetic resonance imaging) studies and electrical recordings reveal that the brains of such patients can respond appropriately to requests even though no outward movement occurs. For instance, one patient was asked to mentally envision a room in her house. Within seconds the patient's brain became active in the same areas that would have become active if the request had been made to a person with a perfectly normal brain. But this activation was not accompanied by any bodily movement.

We routinely encounter mind embedded in disembodied forms in computer programs. One of the most intriguing of such programs, DOCTOR, was devised in the mid-1960s by Joseph Weizenbaum of Massachusetts Institute of Technology (MIT). Dubbed 'Eliza' after the character in George Bernard Shaw's *Pygmalion*, Weizenbaum's computer program analysed language and responded according to script. Although these were the early days of computer programming and far more sophisticated programs have since been developed, Eliza remains relevant to any discussion today of whether the mind can exist without a body.

Eliza modelled the role of a psychotherapist practising nondirective therapy. The patient would make a statement and the program would respond in the manner of the then popular therapy guru Car Rogers.

Patient: 'My boyfriend made me come here.'

Computer: 'Your boyfriend made you come here?'

Patient: 'He says I'm depressed much of the time.'

Computer: 'I'm sorry to hear that you're depressed.'

Etc.

Soon after the introduction of Eliza, Weizenbaum began noticing peculiar behaviour on the part of some of the people who interacted with it. Even though they knew the 'therapist' was only a compute program, they nevertheless began to develop what Weizenbaum described to me during a discussion as ‘powerful delusionary thinking’. ‘Some people were conversing with computers as if they were a person who could be appropriately addressed in intimate terms,’ Weizenbaum commented.

More than a decade before Eliza, the Bletchley Park code-breaker and computer pioneer Alan Turing had suggested a test for determining whether a machine is capable of intelligent behaviour. To pass the Turing test a machine had to fool those interacting with it into believing they were interactin with another human being. Eliza passed the Turing test in those therapy seekers who earnestly believed in the existence of a real-life Dr Eliza capable of helping them to solve their personal problems.

But as critics have pointed out, the Turing test is not a valid test of whether a machine can think intelligently but assesses instead whether the program responds like a human being. The two process are quite different. We have only to look around us to see that human behaviour and intelligent behaviour are not always synonymous.

Eliza and other computer programs developed over the past 50 years suggest, with varying degrees of credibility, that mind can exist without a body.

Not always a top-down process

In any discussion of whether a mind can exist separate from a body it’s important to avoid certain assumptions that may not always be correct. For instance, we usually think of the formation of mind as a top-down process: when the nervous system reaches a certain degree of complexity, mind emerges. But in some instances the process can work in the opposite direction: mind emerges from th body’s interaction with its environment. Take the lowly octopus, for example. Although the octopus seems at first sight to be a very simple creature, its behaviour is actually surprisingly rich. An octopu can selectively reach out and grasp food and other objects, clean its body by brushing its skin with its tentacles, hide from predators and construct homes built from collected shells and stones. An octopus even displays sometimes unsettling examples of apparent intelligence. If you stare into a tank containing an octopus the creature is likely to stare back out at you. If you can muster up the nerve to put your arm into the tank, one of the tentacles may reach towards it and ‘shake’ your hand. Such performances would seem worthy of being dubbed ‘intelligent’, except for one powerful objection. A octopus is essentially a mollusc and close cousin to the snail, one of the dumbest creatures on Earth. How then can an octopus exhibit such impressive indications of intelligence?

For one thing, the body of the octopus differs greatly from that of a snail. It possesses eight powerful legs and seemingly all-seeing eyes. The result is an ability to engage in a complex interaction with its environment. While the snail’s reaction to the world around it is passive and unvarying, the octopus explores the world through the senses of touch and sight. In other words – and this is my point – the mind of an octopus emerges not from a central brain but from the action of its tentacles, eyes and body shape. Thus the mind of an octopus is *embodied* and can be properly understood only by taking its body configuration into account.

Does the mind amount to more than the brain?

A major variant of ‘Can we have a mind without a body?’ is the equally tantalizing question ‘Is the mind more than the brain?’ In our scientific age we take for granted that the brain is the physical bas for the mind. But that wasn’t always so. The New Kingdom Egyptians favoured the heart and treated the brain with indifference. Aristotle also perpetuated this belief in the preeminence of the heart, and yet he did not completely ignore the brain: he suggested that 'the region of the brain' played a role in tempering 'the heat and seething' of the heart. His teacher, Plato, conferred some recognition of the importance of the brain in his theory of the Triune Soul. He suggested that the soul was divided into three parts: the first located in the head and associated with the intellect; the second in the heart and responsible for pride and courage; and the third in the liver, which played a part in lust, greed and other so-called 'lower passions'.

But despite our unhesitating espousal of the importance of the brain over the heart in modern time we still retain in our language some ambivalence about our choice. We speak of experiencing 'heartbreak' when our romances sour; 'It's raining in my heart' lamented the rock 'n' roll pioneer Buddy Holly in one of his songs; our Valentine's Day cards continue to depict Cupid with his arrow piercing a heart and not a brain.

On the brain side of things, we speak of trying to come up with a novel solution to a problem by gathering diverse people together for a 'brainstorming' session; we describe a brilliant student as a 'real brain' who, if he overworks himself, may suffer a 'nervous breakdown'.

Thus concepts concerning the origin and location of the mind don't so much replace each other as learn to coexist. This is true of the most basic question of all, the so-called mind–body dilemma: doe the mind exist apart from the brain? And where does the *soul* stand in all of this?

Much of the mind–soul–body confusion can be traced to the 17th-century French philosopher Rene Descartes. At the basis of Descartes' philosophical position was the proposition that the mind was qualitatively different from the body. According to Descartes: 'The body is regarded as a machine, which, having been made by the hand of God is incomparably better arranged and possesses in itself movements which are more admirable than any of those which can be invented by man.'

The body's responses, however, are not entirely typical of a machine, he added, since they involve communication with a soul. 'But the movements which are thus excited in the brain by the nerves affect in different ways the soul or mind, which is intimately connected with the brain.' That passage is notable for two reasons. First, Descartes had already achieved the pivotal insight that the proper conundrum to be solved was not mind–body but more specifically mind–brain. Second, in that passag Descartes conflates soul (a theological concept) and mind. This confusing mixture of theology, philosophy and science continues to this day.

Since Descartes invoked two interacting but distinct processes – mind and brain – he had to come up with some explanation of how these two very different entities interacted. In an early explanatory attempt to do this Descartes wrote of the 'little gland which exists in the middle of the brain' (the pineal). The pineal gland functioned as an intermediary, making possible the 'Incorporeal Soul in the Bodily Machine'.

But the use of the pineal as an intermediary between mind and brain creates a huge explanatory problem, as pointed out in a letter written to Descartes by Princess Elisabeth of Bohemia, one of Descartes' most highly placed and keenly perceptive students. 'I beg of you to explain to me how the human soul can determine the movement of the body,' she asked Descartes. With this question the princess touched upon a flaw in Descartes' proposal: if the brain can be influenced only in material ways, then how does the immaterial mind interact with it? How does one envision the process whereb something immaterial moves something material?

Descartes' distinction between mind and brain became known as dualism. Those who espouse dualism are referred to – sometimes sneeringly – as dualists. Sneering aside, I think it's safe to say that those who believe in a completely incorporeal mind form a distinct minority today. But on occasion this minority includes people with impressive credentials. Sir John Eccles, who won the Nobel Prize in Medicine in 1963 for his neuroscientific research, believed firmly in the separation of mind from brain. I still treasure a letter he wrote to me after the publication of my first book on the brain. In it he referred to me as a 'promissory materialist'. By that term he meant to imply that I was in agreement with scientists who try to explain the mind in brain terms and, as a result, always promise more than they can deliver. Eccles had a point: neuroscientists are still making claims about the brain that they can't prove. It is not at all self-evident – as some neuroscientists claim – that we can do away with the concept of a mind altogether and simply speak of the brain. Nonetheless, most thinkers today on the relationship of mind and brain favour the view that much of what we refer to when we speak of the mind results from as yet incompletely understood operations of the brain.

Oxford philosopher Gilbert Ryle's *category mistake* offers some assistance here. As Ryle suggeste we should take care not to confuse ourselves by mixing things that can be spoken about together only in a metaphorical sense. Can the chair that I'm now sitting on be related to the theory of evolution? I suppose a novelist or a poet could compose something playful and original linking those two topics, but that creation wouldn't provide a causal connection. Evolution is one thing, chairs are another. Thinking of mind strictly in terms of brain function seems to involve a similar category mistake.

Mind is not a physical structure like the brain; it is not a 'thing'. Mind has no visible form, no aroma, no taste; it can't be held in the hand like the brain. Thoughts, the products of the mind, do not require physicality to exist. Thoughts, however, are meaningless without minds that can think and interpret them.

No final answer

Unfortunately our question 'Can we have a mind without a body?' resists our attempts at a summary answer. We know that the brain contains both large and small structures; it is functionally connected through circuits; it is electrical and chemical in function. But where is mind in all of this? And is the brain the exclusive repository of the mind? Or is the mind a more distributed entity encompassing other bodily communication channels such as our endocrine and immunological systems? A sizeable number of experts are espousing the monist position, where the mind is a catch-all term for all of the things the brain does. But at this point we remain far from capable of explaining how it does these things. Will we ever? Certainly we can expect a deepening understanding of mind and brain and whether we can have a mind without a body. But so far we have no overarching, completely satisfactory theory that explains how the brain 'works' or the exact relationship of mind to brain. But we shouldn't be too critical of our explanatory failure: such a correlation won't be easy to come up with. Philosopher Arthur Schopenhauer referred to this dilemma of explaining the mind–body problem as the 'world knot'. Perhaps that knot will continue to resist our best attempts at unravelling it.

HOW DO BRAINS COME TO EXIST?

The development of the human brain

Before discussing how brains came to exist, it's useful to ask a more fundamental question: what is a brain? Like many profound questions, this one seems, at first blush, easy to answer. Actually, it isn't easy at all.

The first evolutionary step towards a brain occurs in the flatworm where nerve cell bodies are clustered towards the head end. Neuron fibre processes or *nerves* carry signals from sensory receptor to this primitive brain where integration with muscle movements takes place.

Although it's a long and complex journey from flatworms to humans, the key element in defining brain is centralization of the nervous system into the head region. The more complex this arrangement, the greater an animal's responsiveness to its external and internal environments. In ord to stay alive, ancient mammals and birds during the Mesozoic period (250 million to 65 million year ago) evolved brains ten times larger, relative to body weight, than their ancestors. Among the benefit of such large brains were the ability to stay warm by controlling body temperature, the formation of early social networks and the development of parental care, learning and tool use.

Among mammals, not all of the brain structures increased in equal proportion; the same goes for functional use: the brain of each creature is functionally organized to cope best with the world in which it finds itself. The need for increased integration of sensation and movement led to increases i the size of the cerebellum in mammals, the structure at the rear of the brain specializing in balance and coordination. An increase in the number of cells devoted to smell led to the high-resolution olfactory ability that is unique to many animals.

Brain development

All that can be observed at the moment of conception is a single cell resulting from the penetration o the father's sperm into the mother's egg. But within that cell, invisible to the naked eye, resides the DNA blueprint that will direct the construction of the entire human body.

The future brain first becomes apparent about four weeks later with the formation of a spoon-shaped structure only one cell thick known as the neural plate. A groove (the neural groove) runs the length of the neural plate, dividing it into right and left halves.

Even at this early stage of development the future brain possesses three defining characteristics. It is *polarized* (the head is wider and bigger than the remainder of the neural plate); it is *bilaterally symmetrical* (divided into right and left halves on either side of the neural groove); and it is *regionalized* (the wide end of the spoon will become the brain while the handle will develop into the spinal cord).

Next, the two sides of the neural plate fuse to form a tube from which emerge three swellings: the forebrain, midbrain and hindbrain. During the next few months in the womb these swellings enlarge, bend and expand to form the major divisions of the adult brain and nervous system: the cerebrum, th thalamus and hypothalamus, the cerebellum and the spinal cord.

When looked at from the side, only three of the brain's major structures are visible: the cerebral hemispheres, the brain stem immediately below and the cerebellum towards the back of the brain. Al other structures are hidden by the hugely expanded cerebral hemispheres, which represent more than 85 per cent of the brain's weight.

With further development, dramatic changes occur in the cerebral hemispheres. Starting with a smooth billiard-ball appearance at five months' gestation, the hemispheres eventually look like the matching halves of a gnarled walnut four months later. This transformation occurs in order to cram a many nerve cells as possible into the confined space of the skull. The same principle is involved as when you fold clothes before placing them into a suitcase: folding enables you to contain the large surface area of the clothes within the restricted confines of the suitcase. If the cerebral cortex – the thin outer layer of brain cells of the cerebral hemispheres – remained smoothed out instead of wrinkled, it would be about the size of a newspaper front page and we would have to possess a skull the size of an elephant's in order to accommodate its surface area.

Such a large surface area is important, as the cerebral cortex contains almost all of the brain's neurons. However, this rind (*cortex* means 'rind' in Latin) – the consistency of yoghurt – is astoundingly only 2 millimetres thick. It's thinner than an orange peel, yet the cerebral cortex contai two-thirds of all of the 100 billion neurons in the human brain and almost three-quarters of its 100 trillion neuronal connections.

Because it contains so many of the brain's neurons and most of its connections, the cerebral cortex is by far the largest component of the human brain. Comprising a single sheet of neurons and their supporting cells, the cerebral cortex is ten times larger in surface area than the cortex of a macaque monkey and 1,000 times larger than that of a rat. Even more important are the differences in the size of the prefrontal cortex of different animals as a percentage of total brain volume. Less than 4 per ce in cats, 7 per cent in dogs, 10 per cent in monkeys, 20–30 per cent in great apes (e.g. chimpanzees) a 30 per cent in humans.

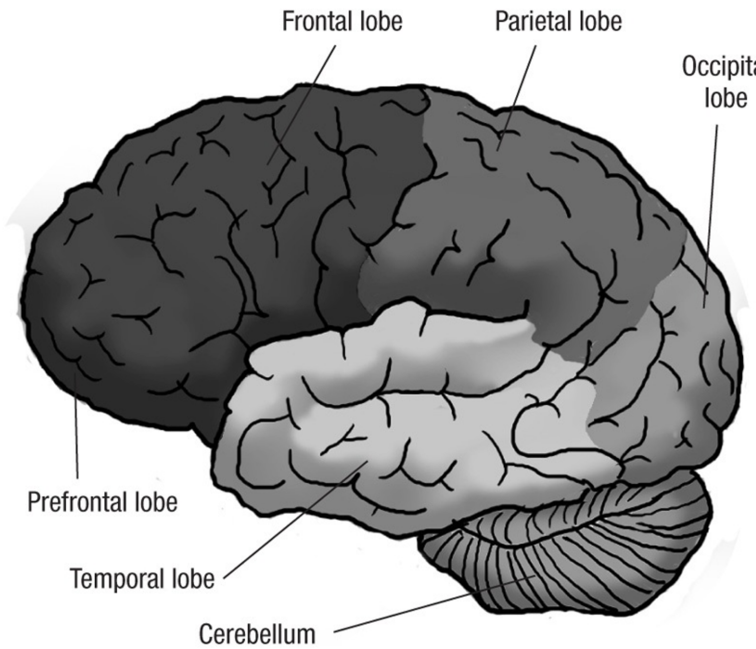
As a result of its size and organizational complexity the cerebral cortex is a much better measurement of intelligence or other cognitive abilities than gross brain size alone. That's because, i general, overall brain size parallels general body size: bigger animals have bigger brains but are not necessarily more intelligent. Compare elephants to humans, for example. Despite the huge intellectu gap between the two species, an adult human's brain is actually about a quarter of the size of an adul elephant's brain. Such observations led early neuroscientists to place less emphasis on measurement of total brain size and concentrate instead on the brain-to-body ratio. Our brains are the largest of all species relative to our body size.

Brain geography

Traditionally, neuroscientists have divided the brain into separate divisions and provided a kind of guidebook for each of the functions performed by each division. While such partitioning is helpful a indeed forms the basis for the medical specialties of neurology and neurosurgery, it's important to remember that these compartmentalized areas aren't absolute divisions based on distinctive differences from one lobe to another but are artificial divisions like property lines or national boundaries. In addition, the various lobes don't exist in isolation but communicate with each other vi association fibres. Indeed, almost 90 per cent of communication within the brain is carried out throu tracts composed of these association fibres whereby the brain 'talks' to itself.

Viewed from the side, each of the overarching cerebral hemispheres resembles an old, wrinkled boxing glove. The front, middle and back of the gloves correspond to the brain's frontal, parietal (from the Latin for 'wall') and occipital ('back of the head') lobes, while the thumb of the boxing glove corresponds to the temporal lobe.

The frontal lobes (one on each side) initiate all actions, including speech. The most anterior portions of each frontal lobe, the prefrontal lobes and supplementary motor cortex, integrate personality with emotion and transform thought into action. Picking up a cup of tea involves the prefrontal lobes deciding on the action, the premotor area programming the sequence of muscle movements necessary and the motor areas activating the muscles of the arms and hands required to carry it out.



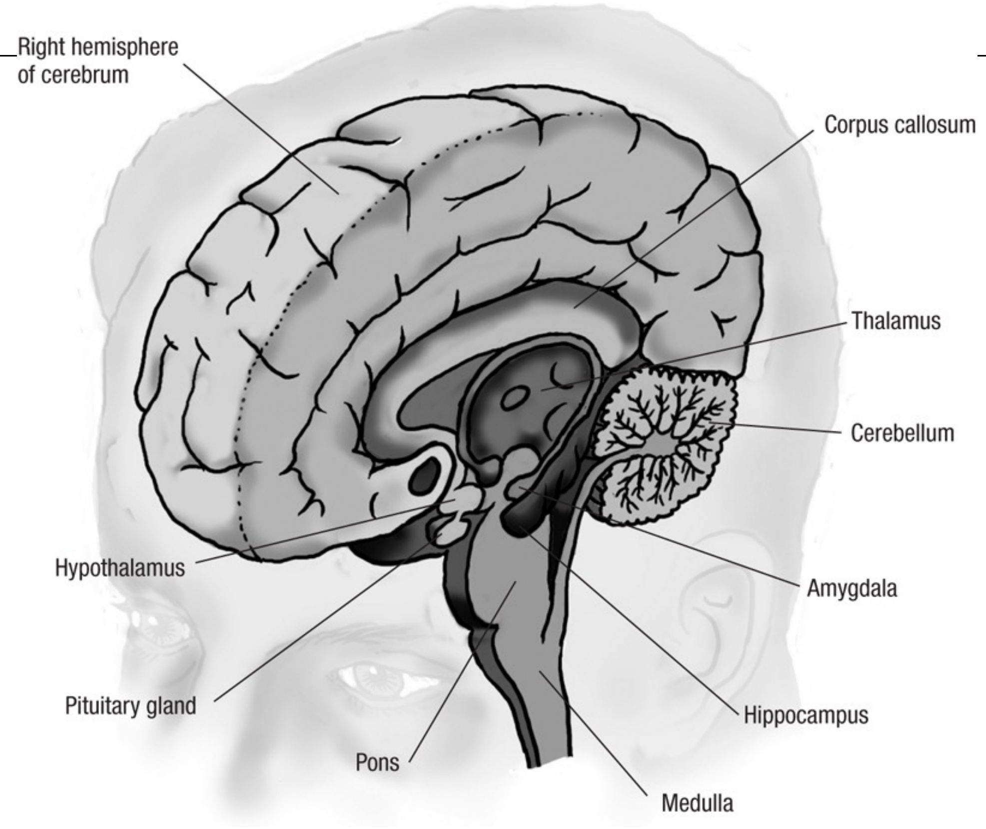
A view of the human brain as seen from the side. Beneath the cerebral hemispheres are the basal ganglia, the centres crucial to involuntary automatic activity.

Each parietal lobe acts as a receiving station for sensations from the opposite side of the body and responsible for integrating that information via the brain's vast networks of association fibres. The temporal lobes are devoted to hearing and merge with the parts of the limbic system (amygdala, hippocampus) that are involved in learning, memory and the experience and expression of emotion.

Finally, the occipital lobe, located farthest back in the brain, processes vision.

Behind the occipital lobe is the cerebellum, a centre involved in movement, balance and coordination. When you watch a ballerina you're witnessing the cerebellum performing at its highest level. But the cerebellum isn't just for balance and coordination, it is also involved with the frontal lobes in the preparatory activities that precede movement.

Viewed from the top, the brain resembles a shard of sea coral, split down the middle by an easily discernable division called the longitudinal fissure. This 'Grand Canyon' divides the cerebrum into the right and left hemispheres, each with different specializations. At the risk of some oversimplification, the left hemisphere is best at reading, writing and other primarily language-based functions. The right hemisphere, among other things, processes visual and spatial matters, as well as analysing the emotional components of speech (tones of voice, revealing hesitations etc.).



A view of one half of the brain after transecting the brain down the middle into two identical halves. This view reveals deep-lying structures that are hidden in the previous diagram.

Connecting the two cerebral hemispheres is a rope-like structure called the corpus callosum, which carries messages from one side of the brain to the other. Since it isn't fully functioning until ten years of age, information transfer in a young child's brain is greatly limited. This first decade of immaturity of the corpus callosum is one of the reasons why few people can recall events that occurred during their infancy and early childhood.

Now let's animate the above summary of cerebral geography. Suppose while reading this sentence you decide to go to the fridge for a Coke. That intention is formulated in your prefrontal and frontal lobes and then organized by the premotor cortex into an action plan that is then whisked to the cerebellum. The cerebellum then enlists the aid of structures lying deep below the cerebral hemispheres (known collectively as the basal ganglia) to translate the get-a-Coke decision into action. All of these brain areas, working in concert, enable you to get up from your chair and walk to the refrigerator. Note that all of this processing – with the exception of you deciding that you wanted a drink – occurs outside of your awareness. If asked about the process you would be comfortable asserting that you 'freely' decided about the soda while everything else was automatic. (In the chapter *Is Free Will an Illusion?* we'll explore whether or not your decision to get a Coke was as freely chosen as it seems.)

A chicken-and-egg question

When we talk about how brains came to exist we encounter a chicken-and-egg question. Is our brain organized as a result of thousands of years of talking and adroit hand manipulation, as is often suggested? Or are these abilities the result of our brain's organization? We know that the brain can be modified by activity: the brain of the concert pianist can be confidently distinguished by imaging and electrical recordings from the brain of the musical ingénue. So it seems to make sense that our brain's organization both reflects our species' experience on this planet while it also determines for us the nature of the 'reality' that we experience.

Part of our reality is logical and reasonable; another part is emotional, capricious and unpredictabl We feel, as well as cogitate. The limbic system, the mediator of all things emotional, consists of interconnected regions forming an emotional circuit deep within the brain. The first hint of an emotional circuit in the brain was provided in 1715 when a Dutch physician and chemist noticed that patients who had been bitten by a rabid animal began 'gnashing their teeth and snarling like a dog'. A autopsy the brains of such unfortunate individuals (as well as the rabid animals that had bitten them) showed inflammation of the limbic system caused, it was later learned, by the rabies virus.

Perhaps it strikes you as appropriate that our mental functioning and our brain's organization should mirror each other: the areas responsible for feeling reside in the deepest, darkest, most central areas, while our rational thoughts and mental processing emanate from our overlying cerebral hemispheres. Thus we 'ascend' from the influence of our 'lower' more emotional centres located in the limbic system towards the 'higher' brain centres in the cerebrum, especially the cerebral cortex. This analogy is consistent with the suggestion first made by the 19th-century neurologist-philosophe John Hughlings Jackson that the cerebral cortex holds in check the more 'primitive' impulses, such a sex and aggression, that arise within the limbic system. Sigmund Freud – a neurologist before he was a psychoanalyst – later incorporated this 'hierarchical' framework (without any reference to neuroanatomy) into his psychoanalytic theory. The ego and superego corresponded to the cerebral cortex while the impulses originating in the id smoulder in the depths of the limbic system from where they periodically erupt.

While a strict separation of higher-rational from lower-emotional processing appeals to our tendency to dichotomize (good–bad, high–low, liberal–conservative etc.), a moment of self-reflectio reveals that our brain doesn't work that way. Think of the last time you were casually sorting through your post and came upon an envelope from the Inland Revenue or other equivalent government entity devoted to collecting taxes or levying fines. You didn't treat this letter as just another piece of mail. Instead it's likely you experienced some form of somatic discomfort somewhere in your body. Perhaps you felt momentarily dizzy or short of breath or vaguely aware of a mild sense of constrictio in your chest or abdomen. Those sensations resulted from your cerebral cortex and limbic system working together to identify this particular item of mail as a potential threat ('Do I owe some tax I have forgotten about?'). In this example, intellectually knowing and emotionally responding are occurring simultaneously not sequentially, at least from the subjective point of view.

The microscopic and molecular brain

So far we've described the brain on the level of what can be seen with the naked eye. But the real action takes place on the microscopic and molecular level. When looked at through a microscope, all brain cells (neurons) show a similar structure. If you allow your imagination free rein you might like their appearance to a tree. Information is carried *to the nerve cell* by thin, sensitive-looking dendrites arranged like twigs or branches. Information going *from the nerve cell* travels along a long taproot-like structure called the axon. Thanks to careful observation under powerful microscopes, neuroscientists know that neurons aren't physically tethered to one another but are separated by a junction, the synapse (a Greek term meaning 'contact').

Far exceeding the neurons by a factor of at least 50 to 1 are the glial cells that help to maintain the brain's structure, speed up the flow of information between neurons and also, as recently discovered, assist neurons in transferring information.

The transfer of information within the brain is both electrical and chemical. First the electrical nerve impulse travels along an axon until it reaches a synapse. It then stimulates the release of chemicals (neurotransmitters) that cross the synapse and upon reaching the other side stimulate electrical activation in an adjoining neuron. Mood and thinking are influenced by the action of these neurotransmitters, as suggested by the beneficial effects on depression exerted by drugs such as Prozac and its successors. Such psychopharmacological effects provide a sobering view of our menta processes. What does it say about our thinking and emotional experiences when they can be affected, perhaps even determined, by manipulations in the concentration and identity of our neurotransmitter and their receptors?

In any consideration of the brain at its cellular level two things are certain. First, the brain's complexity and uniqueness have little to do with its physical composition alone. The brain consists o the common elements carbon, hydrogen, nitrogen and phosphorus, along with a few trace elements thrown in for good measure. Nothing in this simple blend, which exists in all of nature, provides an explanation for the brain's power and uniqueness.

Secondly, many of the chemical messengers used by the brain as agents of communication can be found in single-celled organisms that can be traced back more than 850 million years. So it's safe to say that the earliest living creatures, like ourselves, communicated with each other by a combination of electrical impulses combined with chemical signalling.

Although the exact number of neurotransmitters isn't known for certain, each neurotransmitter has multiple receptors, which helps to explain the marvellous variety and subtlety of the brain's responsiveness. Such receptor multiplicity is one of the reasons why a total 'explanation' of the brain may prove impossible to achieve. Indeed, it's unfeasible to make either large-or small-scale predictions about what will happen in the brain beyond very short timeframes. Still more challenging to fathom is the relationship of events occurring in the brain to the subjective world of our inner thoughts and emotions.

Our situation today can be compared to the world contemplated by cartographers in Columbus's time. That world included territories that were already known about (we know a lot about the macro and molecular functioning of the brain); vast expanses undergoing active exploration (we are learnin about the brain at an exponential rate); and, finally, some territories that remained beyond the limits of even the most creative imaginations.

CAN WE BUILD A SUPER-BRAIN?

Achieving the highest levels of brain performance

Developing a super-brain is a real possibility because brains have plasticity: the capacity to change in response to experience. Without plasticity, the brain would be similar to a computer or machine – comparison sometimes simplistically drawn – and would lack the power of adaptability.

Plasticity is most obvious in infancy. As the brain grows in size and complexity during the first few months of life, its cells interact with the environment and with one another to form networks of connections. Additional experience unites these connections into circuits.

Deprive the infant brain of light, sound and human contact and it will remain stunted. And the importance of plasticity doesn't stop at infancy and childhood but extends into adulthood and old age Think of the brain as a lifelong work-in-progress with plasticity as the underlying dynamic. The brain's transformation in response to life experience can take place over timeframes varying from decades to days, hours and even seconds. Your brain today is different from your brain yesterday because of the effect on your brain of yesterday's and today's experiences.

Thanks to its plasticity, the brain's performance can always be improved through environmental enrichment. We know this as a result of experiments on animals. If you provide laboratory animals such as mice with toys and other intellectual challenges and with treats, the animals perform better o tests of animal intelligence (negotiating mazes, for instance). The same principle holds for us. If we work at the goal of making our world more interesting and novel our brain functions more effectively we become smarter, more successful at meeting mental challenges and – as a bonus for other people more fun to be around.

We create new patterns of brain cell organization according to what we see, what we do, what we imagine and – most important of all – what we learn. Whenever we take in new information we establish new circuits and link with established circuits within the brain's millions of nerve cells. Th brains of laboratory animals provided with more novel and challenging cage environments contain 25 per cent more synaptic connections per neuron than isolated animals. Environmental enrichment leads, in turn, to enhanced brain development and performance. 'Change the experience and you change the brain' is the mantra.

The brain-enhancing effects of language

Building a super-brain should start early in life. Thanks to innovations in brain-imaging techniques, researchers can observe blood flow patterns in the brain of a baby as it sits comfortably on its mother's lap. Using these techniques, researchers have discovered answers to important questions: what brain areas and systems help babies perceive the tiny phonetic units that make up the words and sentences in their native language? Does anything different happen in the brains of infants and young children who are exposed to two languages from their earliest years?

As background, it's important to note that at birth infants from anywhere in the world learn to spea at roughly the same pace, regardless of the language spoken around them. This isn't unexpected since in all spoken languages meaning is conveyed by means of phonemes that correspond to the letters in most written languages. Phonemes are few in number with no more than about 200 different distinct sounds across all of the world’s languages. Only about 38 of these phonemes are used in English.

Infants are born with an innate capacity for discerning phonetic contrast differences among languages the infant has never heard before and may never hear again. In fact, this capacity extends t all of the sounds used in all of the world’s languages. This amazing innate capacity disappears by 10- 12 months. At that point the infant’s sensitivity to phonetic distinctions applies only to the language or languages it hears.

Adults, in contrast to infants less than a year old, experience difficulty in perceiving differences between sounds in a foreign language. This is true even among adults who become quite proficient after learning a second language. For instance, a native English speaker when learning Spanish as an adult often finds it hard to distinguish between *b* and *p* when hearing spoken Spanish. Adult native speakers of Japanese find it hard to discriminate between *r* and *l* in spoken English, requiring contextual clues to decide between word pairs such as *rake* and *lake*.

But such difficulty doesn’t arise in infants exposed from birth to two languages. Bilingual babies when compared to monolingual babies show unique patterns of brain activation coupled with a greate sensitivity to the phonetic units of speech in both languages. Two brain sites are especially important The first, the superior temporal gyrus (STG), is associated with processing the phonemic distinctions between words (‘ba’ versus ‘pa’). The second, the left inferior frontal gyrus (LIFG), is associated wit word meaning and syntax. While the brains of babies speaking only one language showed decreases i activity in the STG when the infant heard a non-native language, this didn’t occur in the brains of bilingual babies, suggesting that these bilingual babies have a linguistic processing advantage. The researcher suggests that early exposure to more than one language extends the 10- to 12-month window where the infant has the ability to process the phonetic range of the world’s languages.

Learning new languages enhances brain function not just in infants and young children but over th entire lifespan. But for those not drawn to learning new languages, there is no need for despair. Learning new words in one’s own language strengthens several brain functions: the language centres located principally in the left hemisphere, and the prefrontal lobes that work on the words and maintain them in working memory (more about that critical function in a moment).

Working components of a super-brain

Components comprising what psychologists refer to as *cognition* are important in forming a super-brain.

Cognition refers to the higher order processing that the brain carries out in order to attend, identify and act. More informally cognition refers to our thoughts, decisions and behaviours along with their accompanying moods. Included here are alertness, concentration, perceptual speed, learning, memory problem-solving, creativity and mental endurance. By working on the following cognitive processes we can inch closer to the achievement of a super-brain.

Attention: Think of attention in the mental sphere as the equivalent of endurance or stamina in the physical sphere. Just as an athlete cannot prevail in a sport without stamina, anyone seeking to develop an optimally functioning brain cannot prevail without attention. This can be improved by exercises such as the following:

Make up a series of 3x5 index cards, each with either the word ‘red’ or the word ‘green’ written on it. ~~On some of the cards make the ink and the word the same colour (the word ‘green’ written in~~ gree ink) while on others mismatch the word and ink colour (‘green’ written in red ink or ‘red’ written in green ink). After shuffling the cards, go through them one at a time and respond to each card in the following ways: if the word ‘red’ or ‘green’ is written in green ink, read the word aloud and tap the table twice. Remain silent and do not tap in response to any word written in red ink. This exercise shouldn’t prove too difficult since you’ve been doing something similar all your adult life: proceedin at traffic lights in response to a green light and stopping in response to a red light. Now redo the attention experiment with this change in the rules: tap and read the word aloud when you encounter red ink but make no tap and say nothing in response to green ink. Proceed as quickly as you can.

As you will discover, this simple exercise is difficult to perform without committing errors. You must remain fully attentive since the required inhibition of your responsiveness changes and is both verbal (speaking in response to only one colour) and motor (acting in response to only one colour). You must overcome the powerful tendency to respond to the written word, when the colour of the ink in which the word is written demands that you make no verbal or tapping response. This difficulty stems, of course, from our lifetime experience of attending to words while largely ignoring the colou the words are printed in.

With this as a preliminary exercise hone your power of attention further by forcing yourself to attend to what is happening around you. Everyday activities, such as shopping, enjoying sport or culture, present readily available opportunities to strengthen attention. What clothes and jewellery ar the people around you wearing? What conversational topics do they introduce and in what order? Think of attention as a conduit for sharpening other cognitive skills, especially memory.

Memory: This is a natural extension of attention. If you pay attention to something you increase your chances of remembering it. We can learn from past experiences, but only those experiences that we can remember. Memory is also the repository of who we are – forgetting constitutes a kind of identity disorder. Conversely, the more things we can remember – up to a point – the richer our personality becomes. On the physical side, each time we learn something new, that new knowledge increases the number and complexity of the brain’s neuronal circuits. Unfortunately, contemporary cultural forces aren’t helpful in building a super power memory. Why bother to remember somethin when you can instantly retrieve the information by a Google search, or quickly bring it up on the screen of a mobile phone? As a result, all of us are threatened with a form of memory atrophy. Fortunately, this can be reversed. The exercise of our memory, just like physical exercise, depends o our personal efforts.

Begin with something simple such as memorizing a string of digits, starting with a list of four digi and working up to lists of nine or ten digits. Write down the lists of digits composed at random and then put the lists away. Later, read each string of digits, look away and then recite the sequence aloud Despite the seeming simplicity of this exercise, memorizing strings of numbers increases the efficiency of the earliest stages of information processing. This is important because the quality of learning depends on how efficiently you process information during the first stages. In addition, digi span has been found to be correlated to reading proficiency, attention, concentration, sequencing, number facility and auditory and visual memory.

Techniques for developing a super power memory