3 ROLE OF THE BRAIN IN MENTAL PROCESSES AND BEHAVIOUR

KEY KNOWLEDGE

- the influence of different approaches over time to understanding the role of the brain, including the brain vs heart debate, mind–body problem, phrenology, first brain experiments and neuroimaging techniques
- the basic structure and function of the central and peripheral nervous systems as communication systems between the body's internal cells and organs and the external world
- the role of the neuron (dendrites, axon, myelin and axon terminals) as the primary functional unit of the nervous system, including the role of glial cells in supporting neuronal function
- the basic structure and function of the hindbrain (cerebellum, medulla), midbrain (reticular formation) and forebrain (hypothalamus, thalamus, cerebrum)
- the role of the cerebral cortex in the processing of complex sensory information, the initiation of voluntary movements, language, symbolic thinking and the regulation of emotion, including localisation of function

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CHAPTER CONTENT

Consider some of what your brain is doing as you read this passage of text. In order to read, symbols are seen on the page, organised into words, and the words are connected with meanings from memory. Then these meanings are combined to form thoughts. While you focus your attention on reading, you are less aware of any background sounds, perhaps the whispers of people around you, the footsteps of someone outside the room or the engines of an overhead plane. You are also less aware of other types of sensory information, such as the pressure of your bottom on the chair and where your arms and legs are. Once you pay attention to any of these, you will become fully aware of them and your brain will start processing that information.

In addition to processing the information you are reading, your brain is performing numerous other functions to keep you alive, such as ensuring that you breathe oxygen, your heart beats, your core body temperature remains within a suitable range and that your digestive system processes any food you have eaten. You are generally unaware of these activities.

Your brain sends and receives messages through its extensive nervous system via the spinal cord to control your breathing, maintaining just the right amount of oxygen in your bloodstream, as well as adjusting your blood pressure to keep fresh oxygenated blood flowing throughout your entire body. Your brain continuously monitors and regulates almost all of the internal conditions in your body. For example, it regulates the nutrient content in your bloodstream, which provides one of the signals to eat again. It also regulates the amount of water your body needs to stay in chemical balance and the activity of the endocrine system that secretes hormones into your bloodstream to help regulate the normal functioning of bodily processes.

Your brain is one of the less obvious features that distinguish you from primates and all other living things. Everything that makes you who you are comes from the way your brain cells interact and connect. It is the source of your consciousness — your awareness of who you are, your state of being and your external environment. It stores all your knowledge and memories, enables you to experience emotions and gives you your personality. Ultimately, it shapes your hopes and dreams for the future. It is the ability of our brain to perform these types of functions that makes us human. But our brain may not look or feel as if it does all this.

COMPLEXITY OF THE BRAIN

If you cupped a human brain in your hands it would feel soft and squishy, like firm jelly. After a couple of minutes, if you turned the brain upside down, you would see a flattened bit left in the tissue from the weight of the brain resting in your hands. This would give you an idea of how delicate it is.

To protect and keep this fragile organ in place, the brain is covered by three transparent, 'skin-like' membranes (the *meninges*) and encased in a hard, bony skull. Also protecting the brain is a watery-like liquid (*cerebrospinal fluid*) that circulates between the membranes. This provides a cushion against knocks to the head, protecting the brain from injury unless the knock is quite hard. The many arteries you can see carry nutrients and oxygen-rich blood throughout the brain. Without this blood, brain tissue quickly dies.

Figure 3.1 The human brain is a complex structure that is involved in virtually everything we think, feel and do.

If you peeled back the membranes you could touch the wrinkly looking surface and feel its many bulges and grooves. This outer layer of tissue (the *cerebral cortex*) covers the largest part of the brain (the *cerebrum*).

If you actually touched the brain of a living person they would not feel anything. Only if you stimulated some part beneath the surface with a low dose of electric current would the person react. The brain receives sensory messages from elsewhere in the body, but has no sensory receptors of its own. For example, there are no pain receptors in the brain tissue itself. That's why surgeons can perform brain operations on patients who are awake.

If you sliced the brain in half, downward through the middle from side to side, you would see its inner features. Although not all features are distinctive to the untrained eye, you would notice that the inside does not all look the same. Both dark and light areas of tissue are visible and these represent different brain parts.

The darker areas, called *grey matter*, are largely composed of nerve cell bodies and their local connections to each other. The outer cerebral cortex layer is entirely made up of grey matter, although it would look more pinkish than grey in a fresh or living brain because of the presence of very thin blood vessels (capillaries). The lighter areas, called *white matter*, are mostly nerve fibres that connect distant brain areas to one another. They have a fatty coating that produces the whitish appearance. White matter is found in abundance beneath the cortex.

Two wing-shaped cavities (*ventricles*) are also easily seen. These are in the cerebrum. They are the largest of the brain's four ventricles which together form an inner communication network. All are filled with cerebrospinal fluid that flows between them.

Despite its fragile look and feel, the brain is the most complex organ in the body and perhaps the most complex natural or artificial structure in the known universe. Its remarkable complexity is largely invisible to the naked eye. You cannot see that it is densely packed with structures, systems, functions, connections and interconnections, many of which are still not fully understood. Within the brain's tissue are roughly 86 billion individual nerve cells called neurons. Each neuron is connected to between 1000 and 15 000 or more other neurons, so there are trillions of connections.

These connections form numerous networks along which information is electro-chemically sent and exchanged. If there were no order to this complexity, it would be extremely difficult to understand brain function. Advances in brain imaging and recording technologies during the past 30 years or so have dramatically increased understanding of brain function. However, psychologists and neuroscientists still know only a fraction of what there is to know about how the brain works.

In this chapter we examine some of the approaches over time to understanding the brain and its role in mental processes and behaviour. We then examine the brain's basic structure and function at the cellular level followed by the roles of specific brain areas.

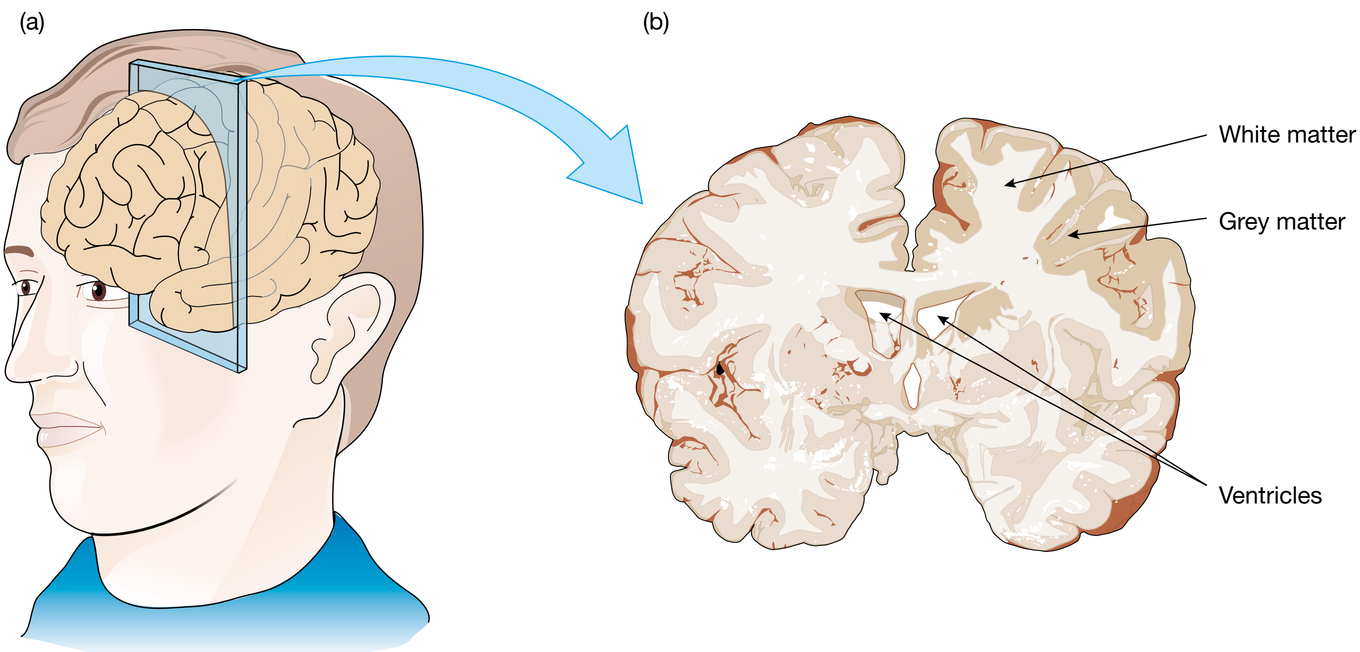

Figure 3.2 Slicing the brain as shown in (a) would reveal inner features such as those in (b).

eBook*plus*

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Weblinks
- Ted talk on 'What is so special about the human brain?' 13 m 31 s
- Neuroanatomy tour of the brain 8 m 08 s

Figure 3.3 The human brain is often described as the most complex natural or artificial structure in the known universe.

LEARNING ACTIVITY 3.1

Reflection

If brain transplants were possible, the identity and personality of the person whose brain is transplanted may be given to another person.

Comment on whether brain transplants should be permitted and explain your view.

APPROACHES OVER TIME TO UNDERSTANDING THE ROLE OF THE BRAIN

The desire to understand ourselves and others has probably existed from the time our early ancestors developed the ability to reflect on their behaviour and that of others. It is possible that they were just as curious as we are today about why we think, feel and behave as we do. Our early ancestors, however, lacked the means to test their ideas and obtain the knowledge they sought.

There is evidence that philosophers in ancient Greece as far back as 2000 years ago spent considerable time contemplating the role of the brain in mental processes and behaviour. But these philosophers could advance understanding only to a certain point. Their ideas were mostly limited to personal observations, reflection, hunches and reasoning.

Although philosophers were good at reasoning, arguing and documenting their ideas, they rarely settled their differences of opinion. This is because their approach to understanding mental processes and behaviour, like our early ancestors, did not enable them to properly test their ideas by conducting scientific research to collect empirical evidence that could support their arguments.

By the nineteenth century, researchers were making progress in answering questions about the brain that philosophers could not. For example, researchers dissected the brains of dead animals or people whose bodies had been donated or sold to medical science. Autopsies were also conducted on people who had died from a brain injury.

Living people and animals were also studied. Valuable information was obtained from studying living people who had experienced a brain injury in an accident or as a result of disease. There were also animal experiments in which parts of the brain were intentionally injured or removed to study the effects on behaviour. Most of the researchers throughout the nineteenth century were physicians, physiologists or anatomists, so research predominantly reflected a biological perspective.

Although early research provided useful information about the brain, this information was mainly limited to the *structure* of the brain, such as which part controlled a specific function. Relatively little was known about the actual *function* of the brain, such as *how* and *when* different brain structures and areas 'work', their relationships to other brain structures and areas, and nerve pathways linking them.

None of the early techniques for studying the brain enabled researchers to directly observe and study the brain functioning as it normally does in a healthy, living person. Consequently, researchers had to mainly rely on making assumptions about underlying brain function based on observations of participants' responses in experimental tasks. In some cases, invasive medical procedures that would not be permissible according to the ethical standards all researchers must now follow.

The development of new technologies during the 20th century in particular helped advance understanding of the brain in significant ways. These technologies have become increasingly sophisticated over time. Researchers can now observe and record images of the brain 'at work' in a healthy, living person in a non-invasive way. For example, researchers have access to very sensitive brain scanning and recording equipment that can reveal the brain areas that are active (and inactive) while a participant responds to some kind of experimental manipulation.

There have been both scientific and non-scientific approaches to understanding the role of the brain in mental processes and behaviour. First, we briefly consider ideas and approaches that relied more on opinion than science, focusing on differing views about the nature and location of the body part believed to be the source of our behaviour. We then examine some of the early brain experiments and the new technologies that promoted scientific investigations of the brain.

Brain versus heart debate

Is our brain or heart the source of our thoughts, feelings and behaviour? The ancient Egyptians didn't think the brain had any role at all. When the pharaoh Tutankhamen was mummified more than 3300 years ago, four vital organs were carefully preserved in jars in his tomb — the liver, lungs, stomach and intestines. There was no jar for his brain or his heart.

The Egyptians believed the heart held the mind and soul and was the source of all wisdom as well as memory, emotion, personality and all life forces. So it was left in its place inside the body. Along with the organs in the jars, it was considered essential to fully take part in the afterlife. The brain, however, was removed with an iron hook through the nostrils and thrown out. It was not considered an asset.

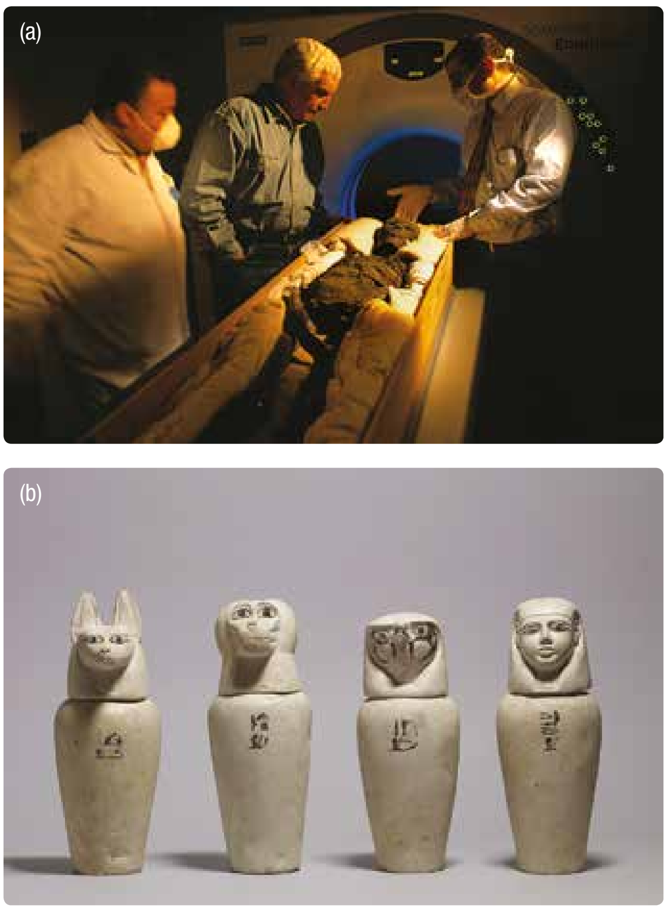


Figure 3.4 (a) A forensic medical expert conducting a CAT scan of the remains of Egyptian pharaoh Tutankhamen. (b) Jars in which the liver, lungs, stomach and intestines of mummified pharoahs were stored. The heart was left inside the body but the brain was considered useless in the afterlife so it was removed and thrown out.

The origin of the brain versus heart debate can be traced back to the writings of the ancient Greek philosophers. Amongst the earliest surviving documented records are those of Alcmaeon and Empedocles. Alcmaeon located mental processes in the brain and therefore took the brain side of the debate. This view is often called the **brain hypothesis**. Empedocles located mental processes in the heart and therefore took the heart side of the debate. This view is called the **heart hypothesis**. The pros and cons of each side were debated for the next 2000 years.

Alcmaeon (about 500 BCE) is widely regarded as the first person to identify the brain as the source of mental processes. He was interested in anatomy and sometimes dissected organs in dead animals. For example, he discovered the optic nerve connecting the eyes to the brain, probably by dissecting an eyeball. This led him to believe that all our senses are connected to the brain in some way. Therefore, the brain was the centre of understanding and played a vital role in perceptions, thoughts and other mental processes. It also followed that if the brain was injured then its functions could be disrupted or stopped (Celesia, 2012; Debernardi et al., 2010).

Empedocles (490–430 BCE) is best known for his proposal that every living and non-living thing in the world is made from four elements — earth, fire, air and water. He reasoned that the heart was the centre of the body's blood vessel system so the human soul

Figure 3.5 The origin of the brain versus heart debate can be traced back more than 2500 years to the ancient Greek philosophers Alcmaeon (brain hypothesis) and Empedocles (heart hypothesis).

is blood and our thoughts must therefore be located in the blood, particularly around the heart. He also argued that our perceptions were formed in the blood and since blood was the means by which we all think (and feel pleasure and pain), the degree of someone's intelligence depended on the composition of the blood (Gross, 1995; Kahn, 2013).

The heart is also where Aristotle (384–322 BCE) located all mental abilities (and the soul) at around 350 BCE. This famous ancient Greek philosopher, who dissected animals to learn about anatomy, gave no role to the brain in behaviour. Instead, he believed that the brain was a cooling mechanism to lower the hot temperature of the blood.

Some well-known physicians (doctors) in ancient Greece, such as Hippocrates (460–370 BCE), who is now regarded as the 'father of medicine', and Herophilus (335–280 BCE), who is called the 'father of anatomy', took the brain side of the debate. They advanced knowledge of the brain and nervous system by scientifically dissecting bodies of people and animals then recording their findings in highly detailed ways for other physicians. For example, Hippocrates wrote that all our emotions 'arise from the brain, and the brain alone' and that with the brain 'we think and understand, see and hear'. However, his views and those of Herophilus about the brain's role were in the minority (Breedlove, Watson & Rosenzweig, 2010).

It was not until the second century that widespread attention was drawn to the brain being very influential in behaviour. This is largely attributed to the work of the Greek physician Galen (c.129–c.216 AD) who argued strongly for the brain hypothesis.

Galen worked as a 'doctor to the gladiators' in first century (AD) Rome where he treated their head injuries and recorded his observations of how their behaviour changed in relation to different wounds. He observed that nerves from sense organs went to the brain and not to the heart, and that brain injury adversely affected behaviour. He also reported on his experiences in attempting to treat wounds to the brain or heart. Galen noted that pressure on certain parts of the brain could affect behaviour such as movement, whereas similar manipulation of the heart did not directly affect behaviour. He also noted that gladiators who died from heart wounds 'keep their reasoning powers as long as they are alive, and this is clear proof that the rational soul does not live in the heart' (Scarborough, 2013).

These were accurate observations but Galen was mistaken with other observations. For example, he incorrectly argued that the important parts of the brain were in the fluid-filled cavities (ventricles) rather than its tissue and that all our physical functions and health depended on the distribution of these fluids along nerves to all body areas (Kolb & Whishaw, 2003; Stirling, 2002).

Galen was a prolific writer and his ideas remained largely unquestioned in medicine for nearly 1500 years until well into the 19th century. However, many of his specific ideas about the brain and its role in mental processes and behaviour were very inaccurate (Breedlove, Watson & Rosenzweig, 2010; Hankinson, 2008).

The brain hypothesis is now universally accepted. There is overwhelming empirical evidence that the brain controls mental processes and behaviour. But it is also known that the function of our heart can affect our thoughts, feelings and behaviour. So, the heart-centred view argued by most of the early philosophers cannot be entirely dismissed.

Figure 3.6 Galen argued strongly for the brain hypothesis on the basis of his work as a doctor to the gladiators in Rome during the first century (AD) where he treated their head injuries and recorded observations of the changes in their behaviour.

Mind–body problem

Another issue debated by the Greek philosophers is called the mind–body problem. This is about the relationship between the human mind and body. More specifically, the **mind–body problem** involves the question of whether our mind and body are distinct, separate entities or whether they are one and the same thing. For instance, is the mind part of the body, or the body part of the mind? If our mind and body are distinct and separate, do they interact? If they interact, how do they interact? And which of the two is in control?

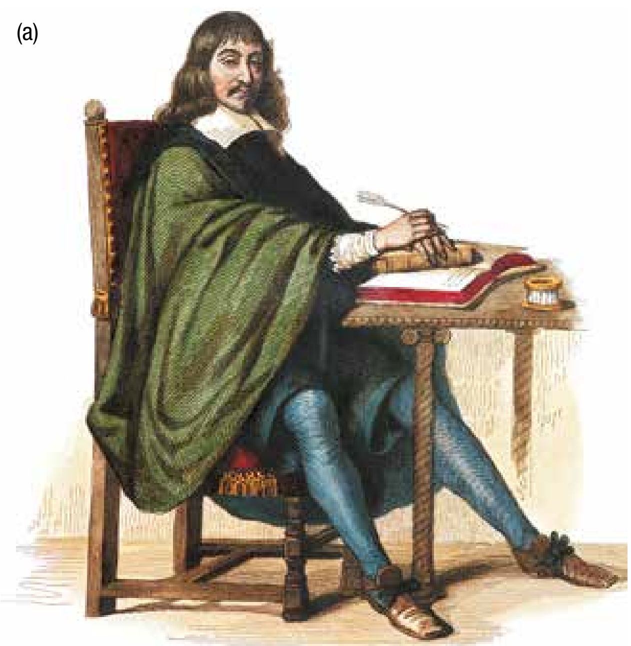
Generally, most of the Greek philosophers believed that the mind and body were separate entities and that the mind could control the body, but the body could not influence the mind. This view was popular for almost 2000 years until it was challenged by French philosopher René Descartes in the seventeenth century.

In his version of a theory called *dualism*, Descartes agreed that the mind and body are two different things. He reasoned that the mind is a non-physical, spiritual entity (i.e. a soul), whereas the body is a physical, fleshy structure (i.e. matter). However, according to Descartes, the mind and body come into contact through the pineal gland, a tiny structure located deep in the brain. This enabled the mind and brain to interact to produce sensations, thoughts, emotions, self-awareness and other conscious experiences.

He identified the pineal gland because it is a single structure near the centre of the brain. The rest of the brain is split into right and left 'halves' enveloped by lots of layers intricately folded within one another. Consequently, it seemed logical that the pineal gland, in being centrally located and isolated from the rest of the brain, could be the centre of consciousness and control behaviour.

Descartes also argued that the mind could affect the body and the body could affect the mind. For example, he believed that mental processes such as memory and imagination were the result of bodily functions, and that emotions such as love, hate and sadness arose from the body and influenced mental states, which could in turn influence the body.

Descartes' understanding of the brain and the roles of its various structures was limited and, at times, wrong. It is now known that people who have a damaged pineal gland or have even had it surgically removed all display normal behaviour. Although located in the brain, the pineal gland is considered to be a part of the endocrine system. It secretes the hormone melatonin that contributes to the setting of the body's biological clock and promotes sleepiness. Thus, although it plays a role in human behaviour, it does not govern it. Nonetheless, Descartes brought the mind, brain and body closer together in a way that others had not previously considered possible.



Mind–brain problem

The different views on the mind–body problem exchanged among philosophers throughout many centuries laid the groundwork for a contemporary version of the problem that has not yet been satisfactorily resolved by psychologists. It is clear that the mind and body are intertwined and that mental processes may be triggered by events in the brain, or that mental processes may, in turn, trigger brain events and therefore influence our behaviour. However, the mind–body problem now tends to be more specifically described in psychology as the mind–brain problem.

The *mind–brain problem* essentially involves questions about the relationship between brain activity and conscious experience; that is, the relationship between what our brain does and our awareness of our own existence and our internal and external environments. For instance, is our mind separate from our brain? Is our mind basically brain activity or is it our inner, personal experience of what our brain does? Is consciousness just one aspect of our mind? Does our mind become aware of what our brain does? If so, is our mind dependent on brain activity in order to become aware? Does our brain trigger conscious experience? Is conscious experience a by-product of brain activity? What comes first, brain activity or conscious experience?

Although there is no universally accepted solution to the mind–brain problem, it is likely that the rapidly advancing discipline of neuroscience will eventually lead psychologists to a better understanding of the relationship between conscious experience and brain activity.

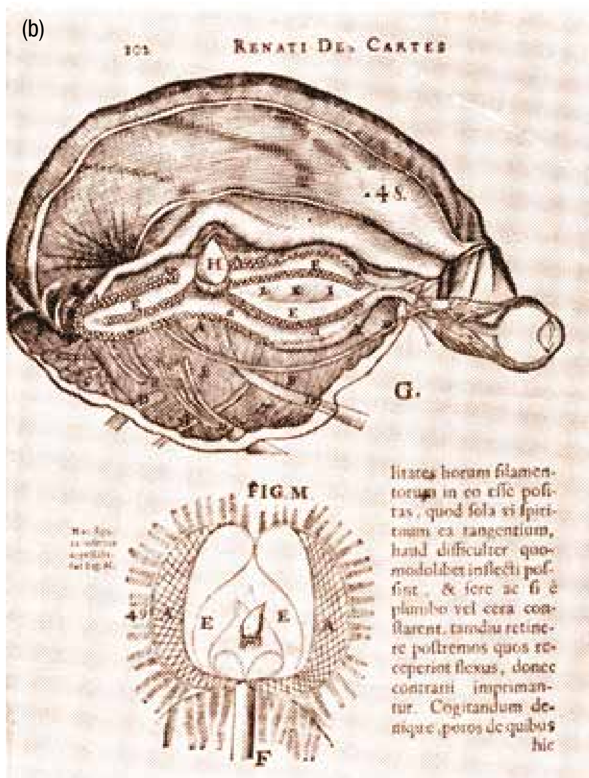


Figure 3.7 (a) French philosopher René Descartes (1596–1650) proposed that the human mind and body are separate but interconnected; (b) Descartes believed that the pineal gland connected the mind and body, enabling them to interact. This original drawing by Descartes shows the brain's pineal gland right in the middle of the brain (H), well located to serve as the centre of consciousness and control behaviour. Descartes is probably best known for his saying, 'I think, therefore I am'.

BOX 3.1 What comes first — conscious experience or brain activity?

The mind–body problem, or mind–brain problem as it is now known, has not yet been resolved in a way that is universally agreed to by contemporary psychologists. However, it is clear that the mind and body are intertwined and that mental processes may be triggered by events in the brain, or that mental processes may, in turn, trigger brain events and therefore influence our behaviour.

Research studies conducted by American psychologist Benjamin Libet in the 1980s showed how the mind–brain problem could be scientifically tested. These studies also provided evidence that activity in the brain may actually *precede* activity of the conscious mind.

Libet's (1985) procedure involved using an EEG (electroencephalogram, page 142) to record the electrical activity in the brains of volunteer participants through sensors placed on their scalps during a decision-making task involving finger movement.

As shown in Figure 3.8a below, participants observed a dot moving rapidly around the face of a clock. Whenever they consciously decided to move their fingers, they had to state the position of the dot at the precise moment of decision-making. An EMG (electromyograph) was used to record the precise moment of finger movement.

Usually, electrical activity is evident in the brain about half a second (535 milliseconds) before a voluntary movement. This is not surprising since brain activity is probably required to initiate a voluntary movement. Libet's results, however, showed that electrical activity was evident *before* each participant made a conscious decision to move. As shown in Figure 3.8b below, the brain became active in less than one quarter of a second (204 milliseconds), which is more than 300 milliseconds before participants reported that they were consciously trying to move their fingers.

According to American psychologist Daniel Wegner (2002), the feeling that we 'consciously will' actions may be a consequence of brain activity rather than a cause. It makes sense that we first consciously think of an action and then perform. However, Libet's research findings suggest that our brain starts the required activity before either the thinking or the doing, possibly preparing the way for both thought and action. It may appear to us that our mind is leading our brain and body, but the order of these events may be the other way around.

Many researchers have replicated Libet's experiments using the same procedures as well as variations with stimuli other than a clock; for example, using sounds. Some have obtained similar results, others have found that the timings of intention and action can actually be the same (which suggests that our intentions are the factors that cause our actions), and still others have found voluntary movement decisions can be initiated unconsciously (which suggests that our actions precede their conscious awareness). In sum, a growing body of evidence suggests that the relationship between neural activity and conscious awareness is more complicated than previously thought (Guggisberg & Mottaz, 2013; Miller, Shepherdson & Treyena, 2011).

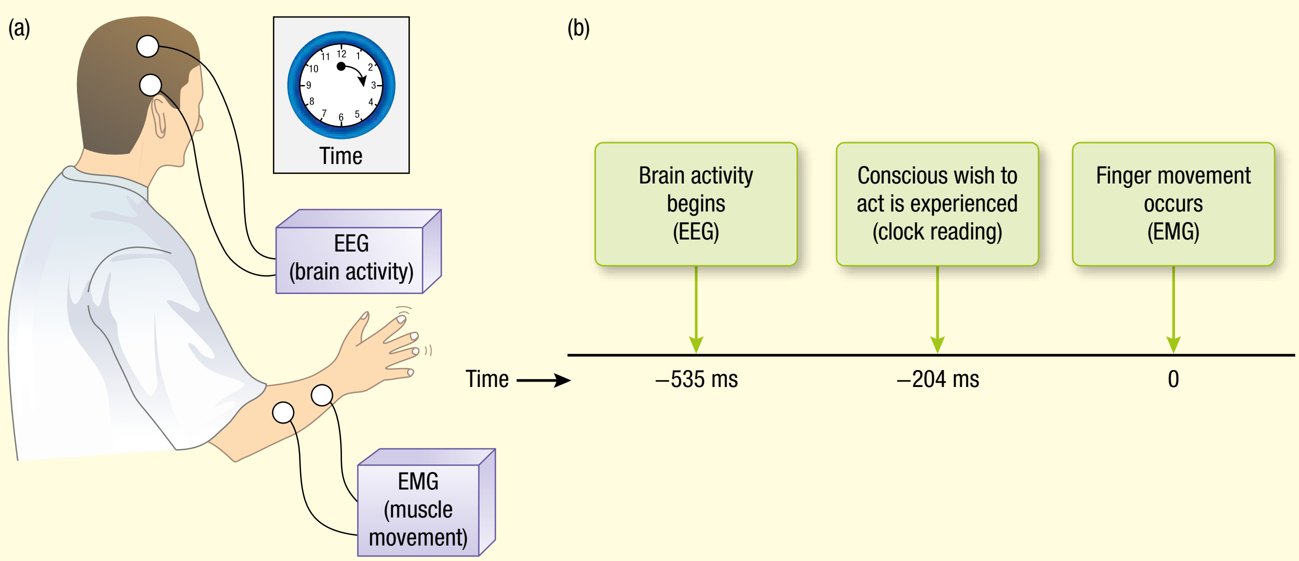


Figure 3.8 (a) In Libet's (1985) experiments, each participant was required to report the exact moment when they consciously made a decision to move their fingers; (b) EEG sensors that detect electrical activity of the brain timed the onset of brain activation and EMG sensors that detect muscular activity timed onset of finger movement.

Source: Adapted from Schacter, D.L., Gilbert, D.T., & Wegner, D.M. (2009). *Psychology*. New York: Worth. p. 297.

Phrenology

Towards the end of the eighteenth century, German physician Franz Gall (1758–1828) proposed that different parts of the brain had different functions. This concept is now known as *localisation of brain function*. Gall took an extreme position that the brain was composed of distinctive, separate parts and that each part had a different function.

Gall argued that personality characteristics and mental abilities were controlled by different parts ('brain organs') which were located on its outer surface. The size of each of these parts indicated how fully developed it was and therefore the strength of its influence. The more it was used, the more it would develop, and vice versa. In addition, the development of a particular part would push out the surrounding skull to the extent that it would cause a bump on the head that could be observed or felt externally.

Gall's view on the relationship between brain and behaviour originated with his observations of classmates when he was at school. He noticed that those with the best memories who achieved better marks than he did had large, bulging eyes. This observation led him to propose that there was a well-developed memory located on the part of the brain directly behind the eyes and this is what caused the eyes to protrude. He had also observed that some of his friends who had similar personality types also had similar shaped heads, with bumps in similar places.

Assisted by his colleague Johann Spurzheim (1776–1832), Gall studied a large number of skulls and skull casts of people with particular talents and unusual or extreme personalities. These included great writers, poets and philosophers, as well as criminals and mentally ill people. They also collected and compared many human and animal skulls to test their theory.

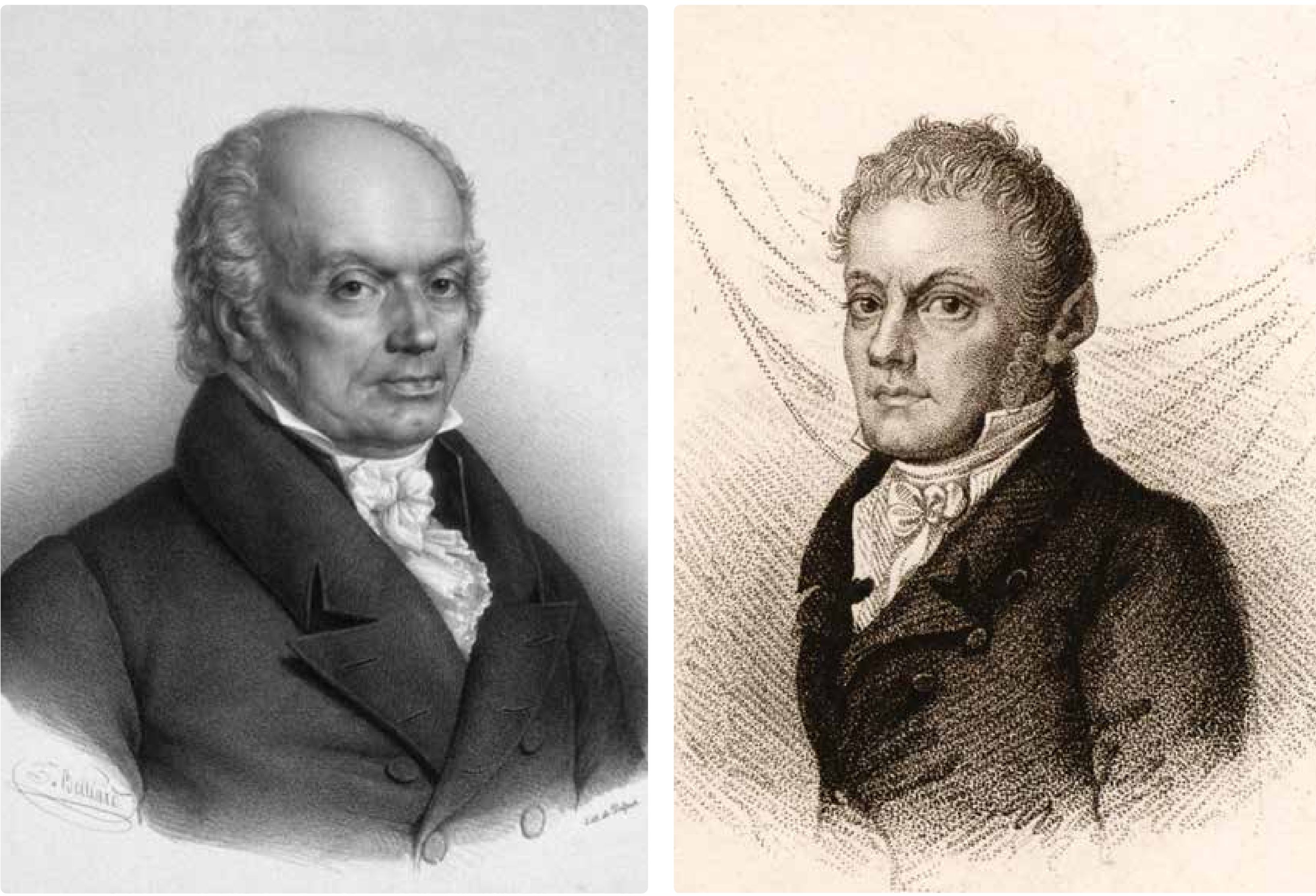


Figure 3.9 Franz Gall (1758–1828) and Johann Spurzheim (1776–1832)

Their research led them to link various mental abilities, personality characteristics and behaviours, called **faculties**, to the skull and consequently underlying brain locations. Figure 3.10 below shows a map of the skull with the locations of 35 different faculties. There were originally 27 faculties and the others were added later by Spurzheim.

The faculties were grouped in two major categories — *affective* (feelings) and *intellectual* faculties, each of which had sub-categories. The sub-category of *propensities* indicated 'internal impulses', whereas the *sentiments* 'designate other feelings, not limited to inclination alone' (Spurzheim, 1827).

Among the faculties was amativeness ('physical love') in the cerebellum at the lower back part of the brain (location 1 in Figure 3.10). A person with a bump there would be expected to have a strong sex drive, whereas a person low in this faculty would have a depression in the same area. Other faculties included:

4. adhesiveness — love of friends and the company of others (bump) vs neglect of friends and avoidance of others (depression)

6. destructiveness — violence and desire to destroy (bump) vs tameness and want of resolution (depression)

8. acquisitiveness — craving for possessions and extremely selfish (bump) vs lavish and wasteful (depression)

17. hope — view the future with much confidence of success (bump) vs gloom and sadness (depression)

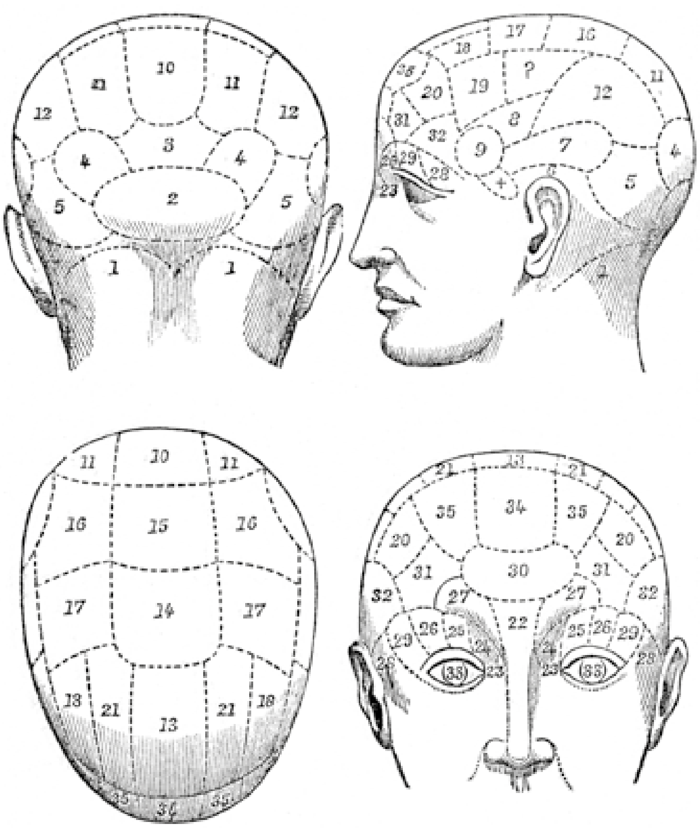
24. size — excellent judge of dimensions and space (bump) vs poor judge (depression)

32. melody — musical appreciation (bump) vs no appreciation (depression).

Gall called his approach *organology*. Spurzheim later renamed it, using the term **phrenology** to describe the study of the relationship between the skull's surface features and a person's personality and behavioural characteristics (faculties). The map showing the location of brain functions on the skull's surface is called a *phrenological map*. Spurzheim successfully promoted phrenology in the UK and the USA where it became very popular. Gall himself never approved of the term phrenology. He would later accuse Spurzheim of misrepresenting his ideas.

Phrenology was exploited by some people as a means of making personality and behavioural assessments. They used a method called *cranioscopy*, in which a device was placed around the skull to measure its bumps and depressions. The measurements were then analysed and linked to a phrenological map to determine the person's likely personality and behavioural characteristics.

Many who practised cranioscopy were 'quacks' and some created their own versions of a phrenological map. Vague or cleverly described interpretations were



AFFECTIVE FACULTIES

I — *Propensities*

1. Amativeness
2. Philoprogenitiveness
3. Inhabitiveness
4. Adhesiveness
5. Combativeness
6. Destructiveness
7. Secretiveness
8. Acquisitiveness
9. Constructiveness

II — *Sentiments*

10. Self-esteem
11. Love of approbation
12. Cautiousness
13. Benevolence
14. Veneration
15. Firmness
16. Conscientiousness
17. Hope
18. Marvellousness
19. Ideality
20. Gaiety or Mirthfulness
21. Imitation

INTELLECTUAL FACULTIES

I — *Perceptive*

22. Individuality
23. Configuration
24. Size
25. Weight and Resistance
26. Colouring
27. Locality
28. Calculation
29. Order
30. Eventuality
31. Time
32. Melody
33. Language

II — *Reflective*

34. Comparison
35. Causality

Figure 3.10 A map used in phrenology to show the relation between the skull's surface features and a person's personality and behavioural characteristics. This map shows the location of 35 'faculties' according to Spurzheim's system published in 1815.