2

The Biological Approach

CHAPTER OUTLINE

LOOKING FOR THE MIND

Most people think of medicine as a profession that takes care of our bodies. Yet sometimes doctors are confronted with cases where the problem seems to go beyond the body. Instead, the focus becomes the individual's awareness of themselves and their surroundings – in short, the mind. Such cases can be extremely puzzling, but may also be useful in helping us understand the mind. Let us briefly consider two such examples.

Oliver Sacks, a neurologist who is also a gifted writer, has described a remarkable case that he encountered (Sacks 1985). 'Dr P.' was a music professor who was referred to Sacks because of a visual problem – he often confused common objects. On one occasion, he thought his wife's head was his hat. Given a live rose to identify, he described it as 'a convoluted red form with a linear green attachment'. Shown photographs, he could identify only those with a distinguishing feature, such as Einstein's unruly hair. On the street, he sometimes patted a fire hydrant, thinking it was the head of a child. Indeed, he could only recognize people by voice, not by sight. Yet his eyes were fine – he could even spot a pin on the floor. In other respects, Dr. P seemed normal; in fact, his musical gifts (with the exception of no longer being able to read music) were considerable. The only evident symptom, apart from his problems with visually recognizing faces and complex shapes, was a slight abnormality of reflexes on the left side. Here was a bizarre puzzle: how could someone find a pin, yet think that his wife's head was a hat? How is our awareness related to what our senses tell us?

phantom limb a mysterious phenomenon in which individuals who have lost a limb will often continue to experience sensations which seem to come from the missing limb.

If that seems puzzling, consider the phenomenon known as **phantom limb**. When individuals lose an arm or other limb, they will often continue to experience sensations which seem to come from the missing limb. Sacks has reported one case of a man who experienced his missing finger as extending straight out – accompanied by the fear that if his hand came near his face, the phantom finger would poke him in the eye! He *knew* the finger didn't exist, but could not escape the sensation, or the accompanying fear. Despite great efforts to understand and treat the problem, the full explanation of phantom limb remains a mystery.

mind the inner subjective experience of conscious awareness; the term has no direct reference to physical form.

Both of these phenomena call into question the relationship between mind and body. Traditionally, **mind** is used to refer to our experience of awareness, or consciousness; it has no direct reference to physical form. The *body*, of course, refers to our physical being, and includes what many feel is the basis of mind – the brain. Are mind and body separate, and does their separateness account for cases like those above? Or are mind and body simply different aspects of an underlying unity? If they are a unity, then what accounts for the sometimes bizarre discrepancies between the two? William James, in his *Principles of Psychology*, stated that, 'The explanation of consciousness [i.e., mind] is the ultimate question for psychology.' Although James made the statement a hundred years ago, and much has been learned since, the answer to the question is still beyond our grasp. However, if we *do* find the answer, many believe it will come from research based on the biological approach.

INTRODUCTION

The biological approach to psychology, as its name implies, views man as a biological organism. What we do, and even what we think, is seen as having its basis in our physical structure. The approach arose out of attempts to understand two major issues: the relationship between mind and body, and the influence of heredity on behaviour. Each is a reflection of our biological nature, and the study of them sometimes overlaps, but the two aspects have separate histories.

As one might guess, biological researchers tend to view behaviour as being purely physical. As a doctor commented while discussing possible physical causes of schizophrenia, 'Of *course* it has to be physical. There isn't anything else up there.' By 'up there', he was referring to the brain. Thus, his reasoning was based on the assumption that the brain determines behaviour. Although you may not find that very surprising, in earlier times it would have been seen as very radical. Even in the seventeenth century, most people believed the body was controlled by an intangible soul. Among those who believed in the soul was the French philosopher René Descartes (noted for his assertion, 'I think, therefore I am'). A keen observer, but also deeply religious, Descartes tried to reconcile the apparent physical nature of the body with the intangible nature of the soul. The human body, he felt, was constructed like that of an animal – both were basically *machines*. However, he also believed that people (unlike animals) had a soul, which interacted with the physical body through a small gland in the brain called the pineal gland. Since in French the same word (*l'âme*) can be used for both 'mind' and 'soul', Descartes' idea came to be interpreted as referring to the relation between the mind and body; his view that mind and body are distinct, but can interact, became known as **dualism**. While Descartes saw the body's functioning in machine-like terms, his interactionist view (physical body interacting with intangible soul) was also a compromise. By separating the mind from the body, dualism created a split which has been the subject of much subsequent controversy (Damasio 1994). Rightly or wrongly, Descartes' concept became so well known that for the better part of two centuries, dualism was the dominant view in Western culture.

dualism the view, first attributed to Descartes, that mind and body are distinct; Descartes believed the two could interact via the pineal gland in the brain.

Despite its long history, dualism poses many contradictions (for example, how can a non-physical mind control a physical body?). Today, researchers in the biological approach reject dualism in favour of *monism*, the belief that mind and body are a single entity. (In most respects this is equivalent to **materialism**, which assumes all behaviour has a physical basis). Materialism avoids many of the problems of Descartes' dualism, but that does not prove it is true. Like dualism, materialism is an *assumption*, and not every person (or every culture) holds the same assumptions about the world. As recently as 1994, researcher Francis Crick (better known as the co-discoverer of the structure of DNA) felt justified in claiming that materialism was 'so alien to the ideas of most people alive today that it can truly be called astonishing' (Crick 1994, p. 3). Still, the materialist view which lies at the heart of the biological approach is increasingly influential in psychology today, and it is worth considering how this came about. Like many changes in our understanding, the shift from dualism to materialism occurred slowly, and was influenced by a series of discoveries.

materialism the assumption that all behaviour has a physiological basis.

Interestingly, one crucial insight came about almost by accident. In 1745 (about one hundred years after Descartes), a French priest-turned-physician named Julien de La Mettrie contracted a fever, and noticed that this physical condition affected his mental state as well as his physical state. Reflecting on this after his recovery, he wrote a book called *L'histoire naturelle de l'âme* (The Natural History of the Soul). In the book, he argued that the body is but a machine, *and* that the soul is no different from the mind. Further, he said the mind was part of the body. This assertion, which clearly went beyond Descartes' position, caused a tremendous outcry, but La Mettrie held fast to his views. Ultimately, the opposition from religious and political authorities forced him to leave France for his personal safety.

By the time of the French Revolution (less than fifty years after La Mettrie), a physician named Cabanis was able to argue that guillotine victims were not conscious after beheading, because consciousness was the function of the brain, just as digestion was the function of the stomach. Still, no one had shown a specific connection between physiological structures and behaviour. Then, in 1861, a French doctor at the insane asylum at Bicêtre, Paul Broca, encountered a case in which a man lost the ability to speak coherently after a head injury. When the man died several years later, Broca was able to demonstrate by an autopsy that the cause of the man's deficit lay in damage to a specific point in the brain. Demonstrating this **localization of function** (connecting a specific behaviour to a specific brain area) was the final step in the progression of ideas. The acceptance of Broca's finding completed the gradual change in attitude, from seeing behaviour as governed by an intangible soul, to the modern view of behaviour as having a physiological basis. Of course, many others also contributed to our current knowledge and ideas. The brief history given here is simply meant to indicate how the basic assumptions about mind and body arose.

localization of function the assumption that specific functions are associated with specific areas of the brain.

heredity the biological transmission of characteristics from one generation to another.

The other main aspect of the biological approach, the role of heredity in behaviour, also had a gradual development. (**Heredity** refers to the biological transmission of characteristics from one generation to another.) In the eighteenth century, people believed that each species of plant and animal had been independently created: as the Bible says, 'every living creature after his kind'. Still, there were indications that this might not be literally true. The great biologist Linnaeus had published a catalogue of over 4,000 plant and animal species in 1735, and his orderly categories suggested connections among species. Then, in 1809, a French naturalist named Lamarck presented the first widely known theory of species development, or evolution. Lamarck believed that variations developed through inheritance of acquired characteristics. For instance, giraffes acquired long necks because each generation strained a little further to get food, slightly stretching their necks, and passed this difference on to their offspring. Today, Lamarckian theory is generally discredited, but it was a significant step forward in suggesting that characteristics have a hereditary basis.

The real revolution in thought came with the work of Charles Darwin. Darwin's theory, published in *The Origin of Species* (1859), was that variations among individuals of a species would occur by chance, but could in turn be passed on. His doctrine of 'survival of the fittest' meant that only those variations which helped the individuals survive long enough to breed would be passed on. Through this process, which he called **natural selection**, Darwin was not only advocating the inheritance of characteristics, but also an evolutionary link between humans and all other species. In 1872 he made this even clearer by writing *The Expression of the Emotions in Man and Animals* (actually, Darwin proposed the concept of inheritance, but specified no biological mechanism for its operation; it remained for the rediscovery of the work of an Austrian monk, Gregor Mendel, for a specific mechanism for heredity to be suggested.)

natural selection the evolutionary process by which those random variations within a species which enhance reproductive success lead to perpetuation of new characteristics; in essence, individuals possessing traits which enhance survival and reproduction are likely to have more offspring

Like La Mettrie, Darwin came into conflict with religious doctrine, this time with the view that man was created 'in God's image'. In part, the controversy concerned how literally one should interpret the biblical concept. The controversy raged for many years, and is still not completely ended, but in time the evolutionary viewpoint expressed by Darwin became dominant. Despite not specifying precisely *how* heredity operated, Darwin's theory laid the basis for the study of hereditary influences on behaviour.

Today, these two concepts – *materialism* and *heredity* – are the foundation of the biological approach to psychology. The assumptions involved (that mind has a physiological basis, and that behaviour can be inherited) influence both the questions asked and the type of data collected. Compared to other approaches, the biological approach emphasizes 'getting inside the black box' – that is, looking at the internal structure of the organism. Broca showed that a specific defect in the brain could destroy speech in an otherwise normal person. Darwin showed that what we are is at least partly due to what our parents are. In this chapter, we will look at how these ideas have been applied to enhance our understanding of behaviour.

THE NATURE OF THE PHYSIOLOGICAL SYSTEM

As previously noted, the biological approach emphasizes the physiological basis of behaviour. While the approach can be applied to any aspect of behaviour, the most challenging questions seem to be those relating to the interactions between mind and body. In everyday life, we encounter situations where the body affects the mind (as when coffee makes you tense), and also situations where the mind affects the body (as when executives get high blood pressure). What is the mechanism of such interactions? In this section, we will try to deal with this question in terms of what is currently known about the physiological basis of behaviour, and also consider some of the problems psychologists face in trying to develop answers.

Mind, Brain and the CNS

In trying to understand the interaction of mind and body, the first difficulty encountered is dealing with the terms involved. For instance, where is 'the mind'? Where is the 'self' that we experience? Terms like these, while seemingly clear in everyday usage, are not so clear when one tries to relate them to physiological structures.

Most people would equate 'mind' with 'brain', and this is partially correct. But in more precise terms, the word 'mind' refers to a psychological concept, not a physiological one; and is usually regarded as the seat of consciousness or awareness, not as a physiological structure. Current knowledge indicates that the brain is, indeed, involved in our experience of consciousness, but no one is currently certain just how, or whether consciousness involves only the brain. So, in discussing interactions of the physical (brain) and mental (mind), one is restricted to saying that somehow the two are connected, or even fundamentally the same, but the specific relationship is not clear. (As noted earlier, in part, this is an assumption that researchers make. However, the alternative – that the mind is non-physical, perhaps a 'soul' – would not only take us back before Descartes, but would also make scientific study irrelevant.) While no final answers can be given here, we will examine what is known about the structure of the physiological system and its influence on behaviour.

FOR FURTHER CONSIDERATION

We all experience conscious awareness, but the connections between this awareness and behaviour are complex. For example, do you breathe in or out when you hit a ball (for instance, in tennis, golf or baseball)? If we are not aware of such things, do you think that means that the mind is separate from the body? Why or why not?

Neurons and the Nervous System

The human body is a remarkably complex system, comprised of trillions of individual living cells of many specialized types. Certain cells in the stomach lining, for example, do nothing but produce digestive secretions. Other cells fight disease, transport oxygen, or store energy. Coordinating the activity of the body's many systems requires communication, which is one of the key functions of the specialized cells which make up the nervous system. These cells, called nerve cells or **neurons**, are like wires in that they carry an electro-chemical message from one point to another. Each time a neuron connects to another neuron, at a junction called a **synapse**, it is possible for a message to be switched to other areas. The *brain*, together with the nerve pathways of the *spinal cord*, forms the **central nervous system** (or **CNS**). Although the brain is responsible for integrating incoming information and directing muscle activity, the spinal cord is a vital relay station. For instance, the first connection (or synapse) between your big toe and the brain is where the pathway enters your spinal cord. For protection, the spinal cord passes within the bones (vertebrae) of the spinal column, like wires in a flexible casing. Despite this protection, a back injury can result in disruption of the spinal cord, which can cause loss of all feeling (sensory input) and movement (motor control) below the point of injury (see Figure 2.1).

The nerve pathways outside the central nervous system form the **peripheral nervous system** (or **PNS**). **Sensory neurons** in the PNS carry messages from the outside world to the CNS via the sense receptors, such as those located in the eyes and ears, while **motor neurons** are responsible for initiating muscle activity, under the direction of the CNS. (The neurons which comprise the CNS are often called **interneurons**, because they are intermediate between sensory and motor neurons.)

The basic unit of the nervous system is the neuron. As noted above, a neuron is like a wire through which an electrical signal passes. This signal, called a **nerve impulse**, stays essentially the same (i.e., in amplitude) as it passes along the 'wire' or *axon*, and is also the same in every neuron (see Figure 2.2 for details of neuron structure). While all neurons show the same basic structure and serve the same basic purpose, they show many differences in their details. One of the most striking variations is in size – the central wire or axon may range from less than 1 millimetre (for neurons in the brain) to about 1 metre (for peripheral neurons between the spinal chord and the toes)! Another difference among neurons is whether they are insulated or not: as with ordinary electrical wires, insulation improves efficiency by reducing signal losses. In neurons, the insulation consists of a fatty substance called *myelin* (the myelin is actually composed of another specialized type of cell called a Schwann cell, which wraps itself around the axon to provide an insulating sheath). Not all neurons in either the CNS or PNS are insulated ('myelinated'), although most of those in the brain of a healthy adult are. The process of forming myelin begins in the foetus, and the

neuron (alt., 'nerve cell') a cell of the nervous system.

synapse the junction between two neurons, represented by a small physical gap which is bridged by the flow of neurotransmitter chemicals from the terminals of the 'sending' neuron.

central nervous system (**CNS**) the brain, together with the nerve pathways of the spinal cord.

peripheral nervous system (**PNS**) those nerve pathways which lie outside the central nervous system, involving sensation, motor control and regulation of internal organs.

sensory neurons neurons in the PNS which carry information from the sense receptors to the CNS.

motor neurons those neurons in the PNS which are responsible for initiating muscle activity.

interneurons neurons which are part of the central nervous system.

Figure 2.1 **The Central and Peripheral Nervous Systems –** As the figure and chart show, the nervous system is sub.divided into various subsystems, with the major distinction being between the CNS (brain and spinal cord) and the PNS (all those nerves not part of the CNS). The somatic system includes both sensory pathways (to the CNS) and motor pathways (from the CNS).

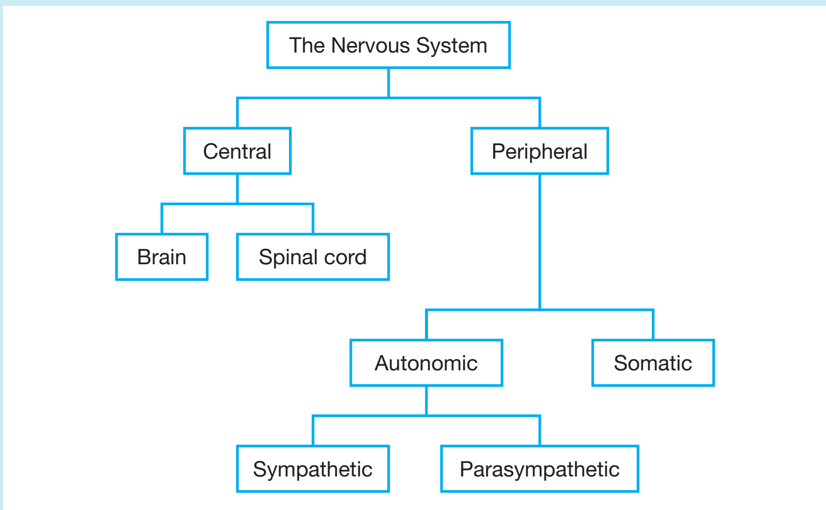
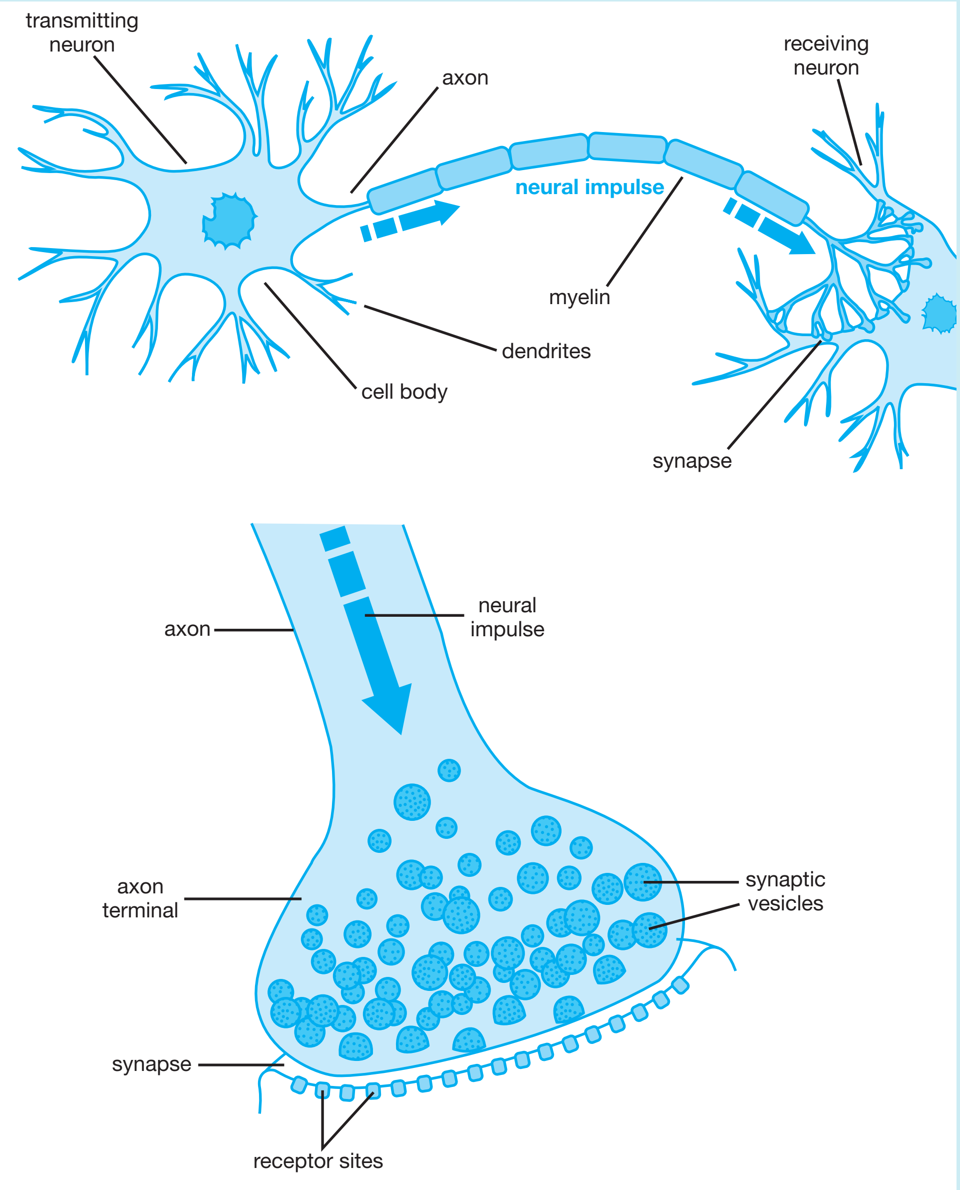


Figure 2.2 **Neurons and Neural Transmission –** The structure of a neuron is illustrated in the upper figure, with the various parts. A neural impulse ('signal') travels from the dendrites, along the axon, to the terminals, where it must cross a physical gap, the synapse. Transmission across the synapse is by means of neurotransmitters, chemicals released by the synaptic vesicles, which then flow across the gap, to lock into receptor sites on the receiving neuron (see lower figure).



nerve impulse the electrical signal generated when a neuron is active, which normally passes from the dendrites, along the axon, to the terminals.

neurotransmitter a chemical released by the terminals of a neuron which plays a role in communication between neurons, across the synapse.

process is largely completed by about age 3, though formation (and repair) continues throughout life. Across species, the degree of completion at birth is roughly paralleled by the degree of behavioural capacities; a new-born calf, for example, is both better myelinated and more capable at birth than a human infant. At the same time, destruction of the myelin sheath (in disorders like multiple sclerosis) can have disastrous effects on the nervous system and behaviour. When the electrical impulse reaches the terminals of the neuron, there is a small physical gap, called a synapse. Communication across the synapse occurs when the nerve impulse triggers the release of chemicals called **neurotransmitters**. As we will see in the next section, neurons can differ in terms of what neurotransmitter chemicals they use.

While the pathways of the peripheral nervous system are crucial in providing our links to the outer world for both sensation and movement, the central nervous system, with responsibility for integrating and controlling the whole system, is much more complex. As noted above, damage to the spinal cord can result in loss of feeling and paralysis; the brain itself is also vulnerable. In the peripheral nervous system, severed nerves will often repair themselves; cases of a severed arm or leg being successfully reattached after an accident attest to this. Unfortunately, nerves in the central nervous system do not regenerate – hence damage to the spinal cord can result in permanent paraplegia.

The Brain

brain the portion of the central nervous system which lies within the skull.

Considered visually, the **brain** is not very impressive – a greyish lump weighing approximately 1.4 kilograms, with an irregular surface of ridges and valleys. However, that superficial impression belies both its complexity and its capabilities. The brain consists of about 100 billion neurons (no one knows the exact number, since estimates are based on examining a small region, and extrapolating the number found to the whole structure). In turn, each neuron makes and receives connections with hundreds or possibly thousands of other neurons, resulting in a network of some one million billion connections in the cortex (the outer layer of the brain) alone (Damasio 1994; Edelman 1992).

Like the nervous system as a whole, the brain can be subdivided into many areas. Early anatomists looked for physical divisions (like the fissures on the cortex, or the almond shape of the amygdala in the limbic system), and then tried to deduce the functions. They assumed that specific functions are associated with specific areas, and this assumption, called *localization of function*, has led to many insights, as we will see. At the same time, the brain is a highly interconnected system, and it is worth keeping that in mind as we discuss what is known about the functions of different parts of the brain.

cortex the pink, somewhat wrinkled outer layer of the brain which controls many of our higher functions like speech and perception; from the Greek for 'bark' (as on a tree).

frontal lobe the area of the cortex in front of the central fissure, and above the lateral fissure; it is involved in the interpretation of emotion and experience.

frontal motor area the area of the frontal lobes just before the central fissure which controls all voluntary movements of the muscles.

parietal lobe the portion of the cortex just behind the central fissure and above the lateral fissure, whose primary function is the sense of touch.

If you were to remove the top portion of a person's skull, you would see the pink, somewhat wrinkled outer layer of the brain, called the **cortex** (Greek for 'bark', as on a tree – See Figure 2.3). Its wrinkled ('convoluted') appearance results from the cortex being folded on itself. Since maximum surface area seems important (simpler organisms have both smaller and less convoluted brains), this crumpling effect allows a large sheet to be compressed into the relatively small confines of the skull. (Imagine crumpling a large sheet of paper into a small wad.)

The cortex is made up of two distinct hemispheres, left and right, each of which essentially controls the opposite side of the body (for example, muscle movements in your right hand are initiated by your left hemisphere). In turn, the hemispheres can be broken down into smaller regions called lobes, which are identified by the valleys or 'fissures' on the surface. Surprisingly, there is considerable variation across individuals in the exact shape and location of the convolutions; despite this, the ridges and valleys make reliable landmarks for distinguishing major regions of the cortex. The two major landmarks are the central fissure, which divides each hemisphere roughly in half front-to-back, and the lateral fissure, which runs along the side of each hemisphere. In each hemisphere, the **frontal lobe** is the area in front of the central fissure, and above the lateral fissure; the portion of the frontal lobes just before the central fissure is called the **frontal motor area**, because it controls all voluntary movements of the muscles. Interestingly, the body areas capable of very subtle motor control (such as the hands or lips) show a greater representation in the frontal motor area than other body regions. In fact, researchers have created maps of the frontal motor area, detailing the body areas controlled. A similar mapping for the sense of touch exists for the portion of the **parietal lobe** just behind the central fissure (See Figure 2.4).

association areas areas of the cortex which have no primary function (such as receiving direct sensory data), but rather play a role in integrating activity from other brain areas.

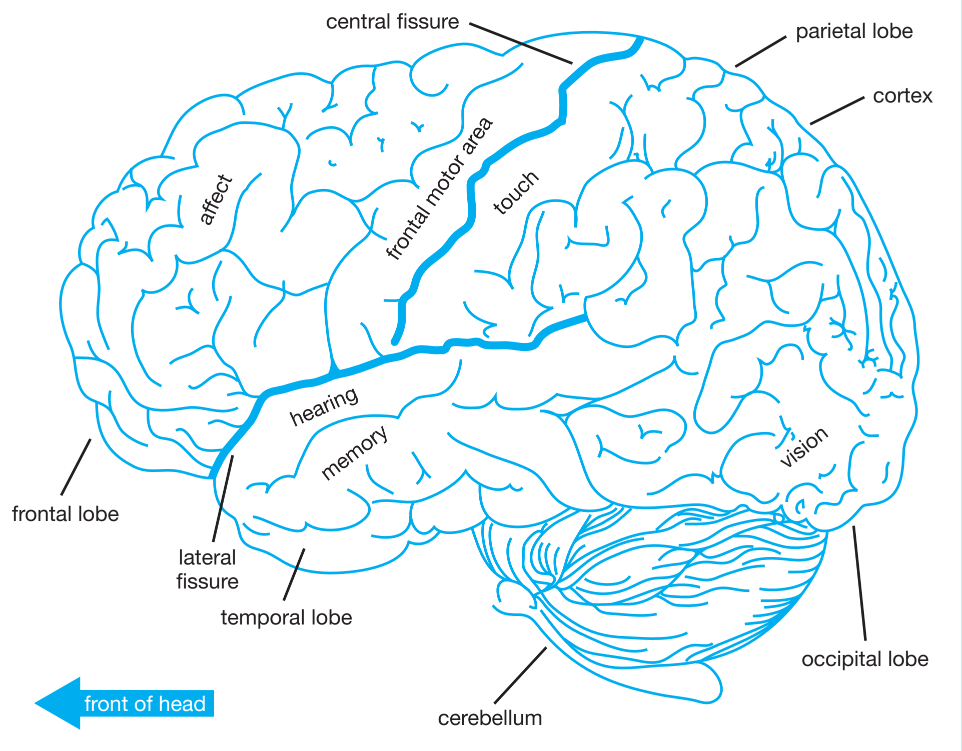
frontal lobotomy an operation, popular in the 1940s and 1950s, which involved sectioning or removing portions of the frontal lobes, in an attempt to treat cases of bipolar mood disorder or chronic pain; later shown to be largely ineffective as a therapeutic procedure.

temporal lobe the region of the cortex below the lateral fissure; its primary functions are hearing and memory.

In contrast to the frontal motor area, much of the frontal lobes seem to have no primary function (such as receiving direct sensory data); such regions of the cortex are referred to as **association areas**. In general, association areas play a role in integrating activity from other brain areas; in the frontal lobe, these areas are involved in decision making and the processing of emotional response (Goldberg 2001). Because of the frontal lobe's role in emotions, an operation called a **frontal lobotomy,** which involved isolating or removing portions of the frontal lobes, was once used in an attempt to treat cases of bipolar mood disorder or chronic pain. The procedure, popular in the 1940s and 1950s, was ultimately shown to be a poor treatment, and frontal lobotomies have been largely abandoned today (Goldstein 1950; Shorter 1997).

We also have some understanding of other portions of the cortex. The **temporal lobe**, located in the region below the lateral fissure, plays a role in hearing, language and memory for objects. In terms of language, a region of the left temporal lobe called Wernicke's area is crucial to make language meaningful. Patients with damage to this area typically have difficulty understanding words and sentences, and produce 'word salads' (sequences of speech which are fluently spoken, but make little sense). The **occipital lobe**, at the rear of the cortex, is devoted solely to vision. Given the large area devoted to it, one might speculate that vision is either very complex, or very important, or both; the evidence suggests that it is indeed both. The experience of seeing, like other senses, is dependent on brain activity as well as sensory activity. In the extreme case, a person with damage to the occipital lobe would be functionally blind, despite having perfectly functioning eyes. Recognition of this connection between brain function and sensory experience is another reason why researchers feel comfortable identifying the mind with the brain.

Figure 2.3 Exterior View of the Cortex, showing the left hemisphere and areas of primary functions.



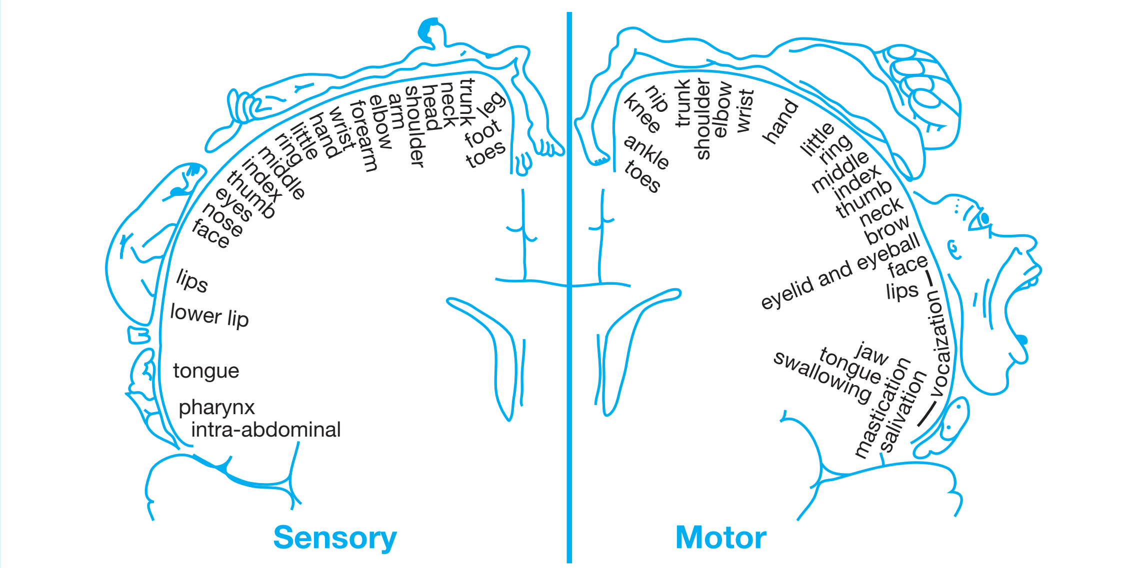


Figure 2.4 **Tactile and Motor Representation in the Cortex –** Penfield's research using electrical stimulation of the cortex has helped clarify the localization of touch and motor control along the central fissure. (In the figure, the brain has been cut vertically along the fissure which divides the frontal motor area from the sensory region of the parietal lobe – compare Figure 2.3.) The relative size of the body parts shows the relative degree of cortical representation. (After Penfield & Rasmussen, 1957.)

occipital lobe the rear-most portion of the cortex, which is devoted solely to vision.

visual agnosia a general term for disorders which result in disruption of visual recognition.

In the introduction to this chapter, we discussed the peculiar case of Dr P., who could see, but often failed to recognize what he saw, including faces. His problem is an example of **visual agnosia**, which refers to problems with visual recognition. Clearly, the primary visual areas of the brain were intact, since he could recognize simple forms like a pin, and had no difficulty avoiding obstacles in his path. Instead, his problem involved integrating the sensory information into a coherent whole, and relating it to other information, such as his memories of people. Disorders like this can be very perplexing, and indeed, in describing this case, Sacks (1985) does not specify the precise regions of the brain affected, or the cause of the damage. However, based on the symptoms, it is likely that it involves the role of the association areas for vision, which link visual sense data to functions in other parts of the brain. In particular, the pattern of problems (trouble in integrating complex patterns, along with abnormal motor reflexes on the left side of the body) suggests damage to the association areas of the right occipital lobe.

While there are clearly differences in the functions of the various parts of the cortex, these functions are often interlinked. For example, when we recognize an object as familiar, we often make use of both sight and touch; the process underlying this can involve complex interactions between the occipital and parietal lobes (James *et al.* 2002). Thus, despite the apparent localization of many cortical functions, we must always remember that the brain functions as a whole.

The cortex received its name (Greek for 'bark') both because of its wrinkled appearance, and because it covers other sections of the brain, much as the bark of a tree covers the interior. Below the cortex are subcortical networks which connect the cortex with other parts of the brain, notably the *limbic system* and the *brain stem*. (see Figure 2.5). These regions are sometimes referred to as the 'primitive brain'. As the name implies, these struc-

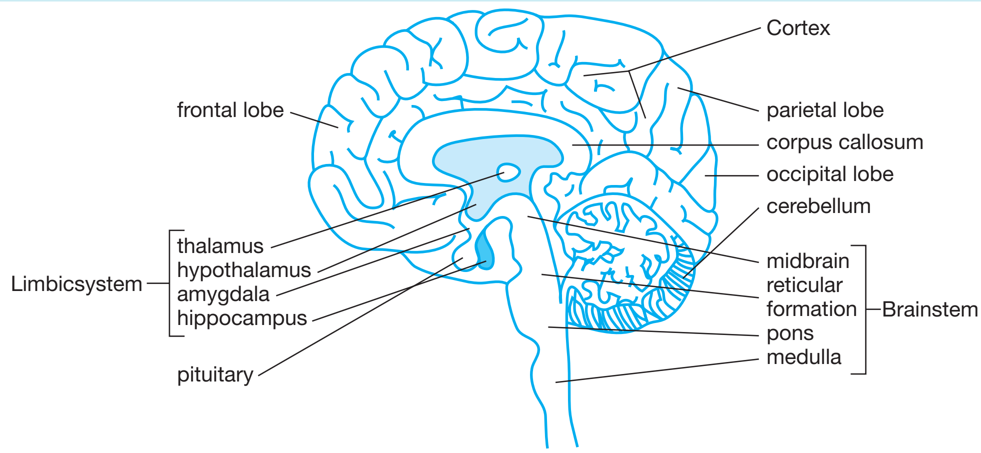


Figure 2.5 **Internal View of the Brain**, showing the relatively 'old' parts of the brain, such as the limbic system, which are normally hidden by the surrounding cortex.

limbic system a series of subcortical structures which connect the cortex with other parts of the brain and which are important in many basic functions; among the main parts of the limbic system are the thalamus, hypothalamus, amygdala and hippocampus.

hypothalamus one of the most important elements in the limbic system, the hypothalamus both regulates behaviours associated with hunger, thirst, sex, and other basic drives, and also plays a role in regulating hormonal functions.

hippocampus a structure within the limbic system which is important to memory function.

amygdala an almond-shaped structure in the limbic system which plays a role in basic emotions, and possibly memory and stimulus evaluation.

tures control fundamental aspects of behaviour that we share with many lower organisms. The main parts of the **limbic system** are identified in Figure 2.5; among these, the most important is the **hypothalamus**, which both regulates behaviours associated with hunger, thirst, sex and other basic drives, and also plays a role in regulating hormonal functions. The **hippocampus** is important to memory function; in a well-known case, a man who suffered damage to the hippocampus lost the ability to retain experiences which occurred subsequent to the surgery, but left prior memories intact. (Milner 1965) The damage disrupted transfer to long-term memory, as will be discussed in Chapter 4. Next to the hippocampus is the **amygdala** (from Latin for 'almond', because of its shape), which plays a role in basic emotions like fear and rage. Emotions are a fundamental, yet complex, part of our behaviour. Research indicates that the amygdala may be involved in aspects of emotion ranging from forming emotional memories (via its links to the hippocampus) to identifying emotionally significant stimuli, such as facial expressions indicating anger or fear (LeDoux 1995; Ohman 2002).

Nestled beneath the large cortical hemispheres, at the back of the head, are two smaller hemispheres. These two hemispheres form the **cerebellum** (literally 'little brain' in Latin). The cerebellum plays an important role in directing movements and balance, particularly fine motor control activities like sewing or playing the piano, and also complex movements like gymnastics. It does this by receiving information from both the sensory nervous system and the cortex, with much of this information passing through an adjacent centre, the brainstem. In addition to guiding movements, the cerebellum also seems to play a role in sensory processing. (Nixon and Passingham 2001).

The **brainstem** is the region at the top of the spinal cord, and is composed of three primary structures: the medulla, the pons, and part of the reticular formation. The **medulla**, a small swelling at the top of the spinal cord, has neurons whose axons extend to the heart and other internal organs; its role is thus to regulate basic bodily processes. Above it, the **pons** (Latin for 'bridge') provides connections between the cortex and cerebellum. A significant structure of the brain stem is the **reticular formation** (reticular means 'finely interwoven'), a diffuse network of nerve fibres which runs through the brain stem and limbic system, with connections both up to the cortex and down to the spinal cord. The reticular formation acts

cerebellum ('little brain' in Latin) two small hemispheres located beneath the cortical hemispheres, at the back of the head; the cerebellum plays an important role in directing movements and balance

brainstem the region at the top of the spinal cord, composed of three primary structures: the medulla, the pons and the midbrain.

medulla a small swelling at the top of the spinal cord composed of the cell bodies of neurons whose axons extend to the heart and other internal organs; its role is to regulate basic bodily processes.

pons (Latin for 'bridge') a region in the brain stem above the medulla which provides connections between the cortex and cerebellum.

reticular formation a diffuse network of nerve fibres which runs through the brainstem and limbic system, with connections both up to the cortex and down to the spinal cord; the reticular formation acts as a relay network controlling sensory inputs, and thereby plays a key role in regulating arousal level, alertness and sleep.

as a relay network, controlling sensory inputs; as such, it plays a key role in regulating our arousal level, controlling alertness and sleep.

Thus, the brain and nervous system are made up of a number of specific structures, which must function as an integrated system to regulate our behaviour. The description given here should not be taken as complete, but simply as an introduction to this incredible system. At the same time, this discussion has said little about how we know these things – for example, how do we know that motor functions are located in the frontal lobe?

FOR FURTHER CONSIDERATION

Based on what we have discussed about the workings of the brain, consider the following science-fiction scenario: A mad scientist kidnaps you, and renders you unconscious. Then he takes your brain, and places it in a bowl that provides nutrients, and is connected to a computer to provide 'sensations'. When you awake, would you be able to tell your brain was no longer in your body? Why or why not?

Studying the Brain

In order to develop an understanding of the brain, researchers have long been dependent on observation. At one time, clinical cases were the primary method available to study the workings of the brain. The use of clinical observation (case studies) has its drawbacks, however, particularly in terms of lack of control. For example, a person may receive a severe blow to the back of the head, and subsequently complain of numbness in one arm. Unfortunately, one cannot easily interpret the connection between the blow and the symptom, because the impact would have been transmitted throughout the skull. Thus, in this case, it does *not* mean that the occipital lobe (the area closest to the site of the blow) is involved in the sense of touch (the symptom). Occasionally, though, the clinical method can lead to important breakthroughs: Broca's discovery of the speech centre is one example. In this case, it was possible to study the patient in detail, since the problem existed for many years. In addition, after the patient's eventual death, an autopsy clearly showed a lesion (tissue injury) in the left frontal lobe, providing the basis for Broca's conclusion. Today, researchers have available a variety of techniques for identifying the function of various brain structures, beyond the use of clinical cases.

Electrical Recording and Stimulation

It has long been known that the brain is somehow involved electrical activity. In ancient Rome, Pliny the Elder recommended the shock of an electric fish, applied to the forehead, to ease the pain of childbirth. Without knowing the mechanism, Pliny recognized that the shock stunned the patient, reducing conscious awareness (including pain). The electrical nature of nerve activity was first recognized by Luigi Galvani, an Italian anatomist, in 1791 when he observed that a frog's leg could be made to twitch at the touch of dissimilar metals. Apparently he first noticed the effect when a butcher used metal tongs to reach for some frogs' legs hanging on a hook Galvani thought, wrongly, that the frog's leg generated the impulse, rather than being activated by the metal tool, which actually created a battery. While it was not long before the true nature of the process was recognized, the possible implications were ignored for nearly a century. It was only about eighty years ago that researchers began to study electrical activity in the brain in a systematic manner.

electroencephalograph (**EEG** – 'writing the electricity of the brain'). a device for recording the electrical activity of the brain by means of electrodes placed on the scalp.

In the 1920s, the first recordings of brain-wave activity (as the electrical signals are called) were made using the **electroencephalograph** (**EEG** – 'writing the electricity of the brain'). The EEG allowed researchers to *record* activity, and is still an important tool today. Recently, EEGs were used to identify synchronized patterns of activity associated with perceptual recognition; researchers found that there was a burst of activity at the moment when an ambiguous visual stimulus was recognized as a face (Rodriguez *et al*. 1999). More dramatically, researchers were able to demonstrate by using EEG recordings that a man paralysed in an accident, and assumed to have lost all cognitive functions, was actually aware. This led to his receiving intensive rehabilitation which enhanced his recovery (Connolly 2001). Despite such successes, a limitation of the EEG is that it is essentially passive, allowing researchers to observe the brain, but not directly alter brain activity.

electrical stimulation of the brain (ESB) artificial stimulation of neurons by means of a current applied through an implanted electrode.

In the 1950s, techniques developed that permitted more direct intervention, by means of **electrical stimulation** of nerve cells (sometimes called **ESB**, for 'electrical stimulation of the brain'). In this technique, small clusters of cells are activated by inserting a fine wire into the desired area, and then applying a small electric current. (Note that since the brain itself has no sense receptors, the simple presence of an electrode does not cause pain or other sensations.) In 1954, researchers at Yale University discovered that electrical stimulation of certain regions of the limbic system and midbrain in animals seemed to trigger aversive reactions (Delgado *et al*. 1954). That is, Delgado's results seemed to identify a *pain* centre that was distinct from a simple sensory response. Then, in the same year, James Olds discovered that stimulation of certain areas of the limbic system could also produce *pleasure* (Olds and Milner 1954). Delgado and Olds were studying areas of the 'primitive brain' (below the cortex) in animals, and the effects they discovered seemed to reflect primitive emotions and drives. These techniques, while striking in their findings, also raised questions: Could the results be applied to people? And what of the cortex? As it happens, initial answers came quickly, due to the work of Wilder Penfield, a neurosurgeon at the Montreal Neurological Institute.

WILDER PENFIELD

— A/W to come —

Wilder Penfield (1891–1976) was born in Spokane, Washington. He was educated at Princeton University, and subsequently attended Oxford University as a Rhodes scholar. It was at Oxford that the direction of his career took shape, as he met the distinguished neurologist Sir Charles Sherrington. After returning to the United States to obtain a medical degree at Johns Hopkins University, he returned to Oxford to study with Sherrington for two more years. Eventually, he established a practice in neurosurgery, first in the USA, and then in Montreal, Canada. At Montreal, he became a professor at McGill University, and founded the Montreal Neurological Institute. This institute became one of the world's leading centres for neurology, and it was here that Penfield did his pioneering work on the mapping of cortical functions. In the course of doing surgery for epilepsy and other disorders, Penfield would identify the functions of various cortical regions by using electrical stimulation as the patient lay conscious on the operating table. This work has been widely hailed, and among other honours, Penfield became a member of the Royal Society. He died in Montreal at the age of 85.

Penfield's discovery occurred while working with individuals suffering from epilepsy; as part of the surgical procedure used to treat the disorder, he identified the effects of stimulation of the cortex in conscious individuals. In many cases, epileptic seizures are triggered by random bursts of activity in a focal region, which then spreads to other parts of the cortex. To treat individuals suffering from severe seizures of this type, Penfield would sometimes operate, destroying cells in the area where the seizure originated. In order to avoid damage to essential functions, Penfield needed to know what functions would be affected by the tissue he planned to remove. To find out, he would first stimulate various areas of the cortex, and observe the effects reported by the patient (who was conscious throughout the operation). From this, he would produce a 'map' of the cortex and its functions, making the surgery itself more accurate. In this way, Penfield was able to help his patients more effectively, and also advance our understanding of the brain.

Electrical stimulation poses some basic questions about the brain and mind. One issue concerns the localization of functions. The materialist view argues that all functions of the mind are based on activity in the body. The simplest form of this view says that each aspect of behaviour is produced by a specific location in the brain – that is, that functions are localized. Broca offered support for this position when he pinpointed speech functions in the left cortical hemisphere. Similarly, Penfield's work indicated that specific regions of the cortex control particular movements, sensations and even memories (refer back to Figure 2–4 for his findings). Thus, it would seem that electrical stimulation may allow us to identify – and ultimately control – all aspects of behaviour. For example, a recent study demonstrated that rats implanted with electrodes and equipped with a tiny video camera could be remotely controlled to explore where the researcher directed (Talwar *et al.* 2002).

This line of thought can give rise to all sorts of scenarios, ranging from people using ESB instead of drugs to control mood, to governments enforcing laws by means of computer-controlled systems implanted in each citizen's brain. These possibilities can seem frightening and Orwellian, and critics have been quick to raise questions. Typically, the questions focus on the moral aspect: who is to control the computers that control the ESB, and what sort of behaviours should be rewarded or punished? But before accepting this as a purely moral crisis, one should look more carefully at the scientific basis of the issue.

Problems do exist with ESB, and in some sense they are all connected with the issue of localization of function. If one accepts it in its simplest form, then there exists a specific centre responsible for any type of behaviour. At present, there is inadequate evidence to support this view. Lower animals show a great degree of physiological predetermination of their behaviour (often called 'instincts'). In humans, however, there appear to be relatively few such patterns, even for comparable behaviour. For example, while male stickleback fish show stereotyped courtship rituals, human males do so only to the extent that their culture dictates. If true localization of function does not exist, one must question whether complete control of every action would ever be possible. A second problem concerns variability across individuals. Gerald Edelman, a Nobel laureate in physiology, has also noted that while the general patterns of brain structure are similar across individuals, the details of neural connections differ significantly. This implies that the mapping of functions must still be done on a case-by-case basis, even if localization exists (Edelman 1992).

While electrical stimulation has greatly aided our understanding of the brain, it does have limitations as a research tool. First of all, ESB is an artificial process. Inserting an electrode destroys a few hundred cells in the immediate vicinity, and the effects of the stimulation itself are not the same as normal neural activity. Typically, the current applied is either some form of alternating current, or a series of brief direct-current pulses. The effect in either case is to artificially stimulate all the neurons in the immediate area, perhaps a few thousand cells. These cells then fire *in synchrony*, which is hardly typical of normal neural function over such a region. Thus, current techniques of ESB initiate brain activity, but do not duplicate the normal workings of the brain. Since there are approximately ten billion neurons in the cortex alone, it is unlikely that ESB will ever mimic the brain's patterns over any significant area. Given these difficulties, it is worth noting that researchers have had more success using electrical stimulation in peripheral nerves (called 'functional electrical stimulation', or FES) than in the CNS. For example, doctors are developing a system to enable paralysed individuals to walk by using FES to stimulate the leg muscles (von Wild *et al.* 2002).

Electrical stimulation has been useful in increasing our understanding of the brain. In addition, clinical work like Penfield's has led to better, simpler methods of treating disorders like epilepsy. At the same time, it is inherently limited, in that it cannot tell us how the brain functions as a whole. This means that larger-scale functions, like consciousness, are unlikely to be revealed by ESB. For that, we must look to other approaches.

FOR FURTHER CONSIDERATION

If technical and ethical constraints did not prevent it, would you be interested in having electrodes planted in a pleasure centre of your brain? What would be the advantages and disadvantages?

Computerized Imaging Techniques

computerized imaging techniques for studying brain function which use computers to convert information into a three-dimensional model of the brain which can be viewed on a television monitor.

More recently, a variety of techniques have been developed to study brain activity across large regions of the brain. These **computerized imaging** techniques, which use computers to assist in the analysis of information, are enabling researchers to gain new insights about brain function (Barinag 1997; Kevles 1996). While the details of each technique differ, they are similar in that the computer is used to convert a series of two-dimensional images into a three-dimensional model of the brain which can be viewed on a television monitor. The first technique, the CAT scan, was developed by British engineer Godfrey Hounsfield in 1971. It uses a series of X-ray images which are combined by a computer to create a 3-D picture of the brain. The limitation of the CAT scan, however, is that, like any X-ray, it shows physical structures, but reveals nothing about the *activity* within the brain.

positron emission tomography (PET) a technique for studying brain activity by monitoring the absorption of a radioactive tracer injected via the bloodstream.

Since the development of the CAT scan, newer techniques have provided doctors and researchers with more detailed information about the brain. In **positron emission tomography (PET)** scans, a short-lived radioactive substance is injected into the bloodstream along with glucose, which is used by cells (including brain cells) for energy. Consequently, when the injection is given, the active areas of the brain absorb more of the glucose, and with it, the radioactive tracer. Sensitive detectors then pinpoint the location of the tracer – and thereby tell researchers which parts of the brain are most active. PET scans have been used to study links between brain function and a variety of cognitive processes – for example, the role of the frontal lobes in language (Ravnkilde *et al*. 2002), While PET scans are very useful in helping to study activity in the brain, they have two significant limitations: the use of a radioactive tracer is rather invasive, and activity patterns must be averaged over intervals of about 30 seconds, because the absorption of glucose occurs gradually.

Figure 2.5x PET Scans of Brain Activity – These images of the left hemisphere show how PET scans can show changes in the pattern of brain activity associated with different behaviours. In these images, the (color?) areas indicate regions with highest activity.

— A/W to come —

magnetic resonance imaging (MRI) a technique for studying the brain by observing the effects on electrical charges in cells in a rapidly changing magnetic field; variants can be used to study either body structures or activity.

By contrast, **magnetic resonance** scans (variously identified as either 'nuclear magnetic resonance' or 'magnetic resonance imaging' scans) do not require injection of a radioactive tracer; instead, they utilize the response of electric charges within cells to a rapidly changing magnetic field – a process called resonance. Depending on how it is used, magnetic resonance can be used to study structures or activity patterns; the latter is often referred to as *fMRI*, for 'functional magnetic resonance imaging'. Because it does not depend on the use of a radioactive tracer, magnetic resonance is non-invasive, and fMRI is able to identify activity changes over intervals of only a few seconds – both of which make it somewhat more attractive than PET scans. The use of fMRI has enhanced our understanding of important aspects of brain function; for example, the study of cerebellar activity during sensory and motor tasks has led to recognition that the cerebellum does more than coordinate movement (Gao *et al.* 1996). More recently, MRIs have indicated that Penfield's classic mapping of the cortex (see Figure 2.4) may contain errors in the regions associated with the face; in particular, the parts associated with the forehead and chin should be reversed (Servos *et al.* 1999).

The new generation of scanning techniques provide a powerful tool for research into brain functions, enabling researchers to examine aspects of brain function never before possible. At the same time, scanning methods also assist in the treatment of a range of disorders. For example, PET scans have identified markedly reduced activity in the cortex of depressed patients compared to normal individuals, and reduced frontal-lobe activity in individuals with schizophrenia (Kasper *et al.* 2002). Further, they can help assess the effectiveness of drugs used in treating depression (Drevets *et al.* 2002). MRI scans have proved equally useful: by using fMRI to study language in bilingual individuals, researchers were able to identify different areas of the frontal lobes involved in native language, compared to a second language learned as an adult. This helps to explain why bilingual stroke victims sometimes only lose one language, and has implications for therapy (Kim *et al.*, 1997).

While very useful, computerized scanning techniques also have two major limitations: First, they are very expensive, and their use is unlikely to become routine for some time to come. Second, at present they are limited in their ability to pinpoint the location of activity precisely – far less than electrical stimulation, for example. However, since PET scans and magnetic resonance are fairly recent, further improvements are likely to be seen in the future.

Each of the above methods has contributed in different ways, to our understanding of the brain. In many cases, the evidence seems to support the concept of localization of function. However, one must remember that the brain is highly interconnected, and its activity is highly integrated (it is worth noting that more of the brain is devoted to integration, via association areas, than to primary functions). Despite the existence of specialized functions, no one part can really be considered alone (an analogy might be an automobile: examining one part, such as the transmission, will not reveal the way the system as a whole functions). As the example of Dr P. (the music professor described by Oliver Sacks) shows, we see the psychological processes most clearly when considering the whole brain.

FOR FURTHER CONSIDERATION

If you had access to scanning equipment, what aspect of behaviour would you choose to study?

Chemical Processes in Behaviour

As discussed in the preceding section, the CNS plays an essential role in coordinating behaviour. Neurons transmit sensory messages and allow motor responses to occur almost instantaneously; the process of touching a hot stove and quickly removing one's hand is a good example. (This represents an example of a so-called *spinal reflex arc*, the simplest form of neural circuit; it involves only a sensory neuron and a motor neuron, which connect via a synapse in the spinal cord.) Despite the impression we may have from such experiences, nerve conduction is not truly instantaneous: the fastest speed for nerve impulses is about 150 metres per second in large myelinated sensory nerves, slowing to a mere tenth of a metre per second (point-to-point) in the brain stem. Our **reaction time** to respond to a stimulus is a reflection of the limits of this communication system. For example, when driving a car, it takes about three-quarters of a second to begin lifting your foot off the gas, from the moment of seeing something you should stop for. At 80 kph, you cover almost 17 metres in that time – and that doesn't count the time for the brakes to physically stop the car!

reaction time the time required to make a response to a stimulus, as measured by the interval between the stimulus and the response.

Neurotransmitters

Despite being less than instantaneous, the nervous system is very effective in fulfilling its role as the body's communication network. Messages continually criss-cross, enabling us to perceive and respond to both our internal and external environments. In this system, the primary signals are the nerve impulses, racing along the axons. While the axon of a neuron may be compared to a wire which relays an electrical signal, a nerve impulse only travels within the neuron which generated it. At the junction between two neurons is a physical gap, the *synapse*. In order to bridge this gap, communication between neurons depends on an exchange of chemicals. These chemicals, called *neurotransmitters*, are released by the terminals of one neuron, and flow across the synaptic gap to the receptors of the next neuron.

The first neurotransmitter to be identified was *acetylcholine*, which is released by motor neurons to activate muscle fibres; in the CNS, it has been implicated in learning and memory (Butt *et al*. 1997). Since acetylcholine was first identified in the 1930s, approximately 100

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Figure 2.6 Major Neurotransmitters and their Functions – A range of neurotransmitters exist in the nervous system, often serving different functions in different parts of the brain.

Neurotransmitter	*Where found in nervous system*	*Examples of functions*
Acetylcholine	Throughout the brain Neuromuscular synapses	Learning and memory Control of muscles
Dopamine	Many locations, including Cerebellum, basal ganglia, Limbic system	Motor activity, coordination Emotion and memory
Epinephrine	Many locations, including sympathetic nervous system	Emotion, stress
GABA	Major inhibitory neurotransmitter found throughout brain	Anxiety, arousal, learning
Glutamate	Major excitatory neurotransmitter, found throughout the nervous system	Anxiety, mood
Serotonin	Many locations, including thalamus, brainstem	Sensory processing Sleep, arousal

chemicals have been found which are involved in neural transmission. (Cooper, Bloom and Roth 1991). *Dopamine*, for example, plays a role in both motor control and sensory processing; low levels in motor pathways result in Parkinson's disease, while high levels in sensory pathways have been partially linked to schizophrenia. A study found that playing battle-simulation video games raises dopamine levels, which may account for their 'addictive' attraction to players (Koepp *et al.* 1998). While it is not possible to review all the types of transmitters, it is worth noting some basic concepts of neurotransmitter function. (see Figure 2.6 for an overview of some of the major neurotransmitters and their functions).

Neurotransmitter substances can function in various ways. Some neurotransmitters trigger activation of the neuron, called *excitation*; this is a bit like stepping on the gas while driving a car. Others act to prevent the neuron from firing, called *inhibition*; by reducing neural activity, this is somewhat like stepping on the brakes while driving. Still other substances act to block the excitatory or inhibitory chemicals, or to clear them away after they have done their job. As we will see when we discuss drug effects, this system provides the basis for a wide range of outcomes.

While well adapted to providing quick responses, neuronal control has its limitations. Neurons only communicate while they are active, and while changes in activity can take place over fractions of a second, a neuron cannot remain active indefinitely. Faced with constant stimulation, neurons begin to reduce their response, a phenomenon called **habituation**. This means that the nervous system is not well suited to the regulation of slower-changing processes like metabolism, growth and reproduction. To understand how such processes are regulated, we must look at another type of chemical process.

habituation a reduction in neural response due to continual stimulation.

hormone a chemical secreted by an endocrine gland; hormones are involved in many aspects of metabolism and long-term functioning of the body.

endocrine glands (ductless glands) glands which secrete chemicals called hormones directly into the bloodstream.

Hormones

In contrast to the transient processes of nerve conduction, some bodily processes are based on another class of chemicals produced by glandular cells. These cells 'communicate' by means of chemical secretions. The most significant glands, from this standpoint, are the **endocrine glands**. These are a number of glands which secrete chemicals called **hormones** directly into the bloodstream, where they are carried to all parts of the body (see Figure 2.7).

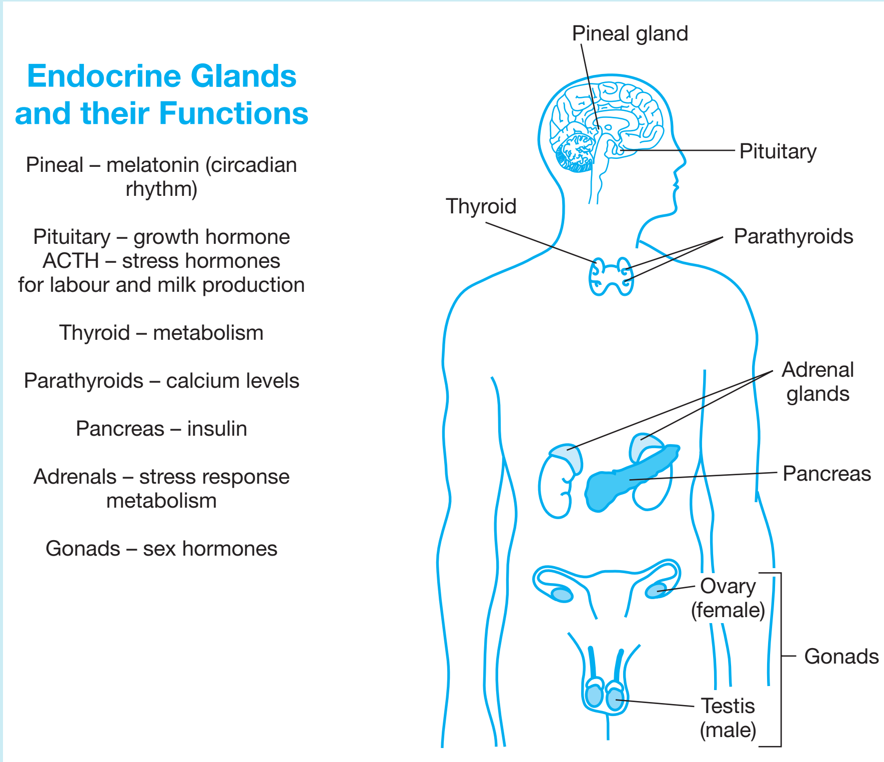


Figure 2.7 **The Endocrine System and Hormonal Functions –** The major hormone.secreting glands are illustrated, along with the functions of some of the major hormones produced.

Given the time it takes for circulation through the body, the effects of these chemical messengers are not as swift as neural transmission – often it can be minutes, hours, weeks, or longer before the response occurs. Not surprisingly, though, the effects are typically much longer-lasting than those processes which are under direct neural control. In this sense, neural and hormonal processes are not competitive, but complementary.

At one time, the distinctions between neural and hormonal processes seemed both clear-cut and neat: the nervous system handled short-term functions with fast responses, and the endocrine system handled slower, long-term functions. But, research in the past decade has shown that the boundaries are not quite so distinct. One reason for this view is the realization that the two systems directly interact. The *pituitary gland*, for example, which is sometimes called ‘the master gland’ because of its role in regulating other endocrine glands, also has direct linkages to the hypothalamus, whereby it can influence the nervous system. The hypothalamus, in turn, releases small amounts of hormones, which affect the endocrine system. While such interactions actually make sense – links between the systems presumably let the body function more effectively overall – it makes separating their roles much harder. A couple of examples will indicate the concept. *Norepinephrine* (also called noradrenaline) is one example of such dual-purpose chemicals: It is one of the primary secretions of the adrenal glands, and also a neurotransmitter found in many parts of the nervous system (the neurons which use it as a neurotransmitter are called ‘noradrenergic pathways’). *Vasopressin*, first identified as a hormone which influences blood pressure, is also used as a neurotransmitter by the hypothalamus, and has been shown to enhance memory and learning. While the method of delivery for neurotransmitters differs (i.e., release into the synapse, or into the bloodstream), both processes involve receptors on the target (a neuron or a bodily organ), which are activated when the appropriate chemical binds to the receptor.

In addition, it has been discovered that some chemicals influence neural transmission, while retaining their roles as hormones. One example is the family of chemicals called *endorphins*, which can enhance our mood and reduce pain (Hoffman 1997). (The function of endorphins will be discussed further in relation to drug effects.) Variously called **neuropeptides** (a peptide is a short chain of amino acids) or neurohormones, they have further influenced our ideas about how the body functions, even as we try to puzzle out their role (Cooper, Bloom and Roth 1991). As time goes on, our understanding of the chemical processes which underlie behaviour will doubtless increase. At present, the new-found complexity is exciting, even as it reminds us never to assume that we have the complete picture.

neuropeptide a chemical, comprised of a short chain of amino acids, which can function both as a neurotransmitter and as a hormone; also called a neurohormone.

FOR FURTHER CONSIDERATION

Given that chemical processes are so important to the regulation of the nervous system, do you find it plausible that mental disorders could be caused by biochemical disturbances in the brain? What evidence would you look for?

INTERACTIONS OF MIND AND BODY IN BEHAVIOUR

Both neural and chemical processes are important to our understanding of the relationship between the brain and behaviour. In this chapter, we cannot cover all that is known about these processes. Rather, the intention is to give a basic description of how these physiological processes fit into the biological approach as a means of understanding behaviour. At the beginning of this chapter, we noted that the biological approach assumes that the mind is ultimately a product of the brain, with a physical basis. This assumption is often referred to as *materialism*. At the same time, no one can presently explain precisely *how* mind and brain are connected, despite the progress made in understanding more basic functions. A person may be a type of 'machine' in the materialist sense, but it is an exceedingly complex machine. To help us understand this more clearly, we will examine some of the interactions between mind and body.

As already noted, it is impossible to identify the 'mind' with one particular brain structure, or portion of the body. Consciousness may depend on a normally functioning cortex, but other aspects of behaviour depend on other elements of the system. If we cannot localize the mind to a specific structure in the body, then how is it possible to study interactions of the two? It is precisely because mind and body are separate conceptually, and require different types of description, that one can seek parallels. It is almost like trying to translate between two languages – words may not always be easy to match up, but in the end the ideas can be communicated. In this case, we are trying to translate between physiologically-based 'body', and psychologically-based 'mind'.

The Effects of Body on Mind

When we speak of effects of the body on the mind, we are referring to the effects of physically identifiable events (for example, changes within the body) on psychological functioning and behaviour. Nearly all of the identifiable events can be described in terms of neural and/or chemical processes. Obviously, this can include a wide range of effects, both transitory (such as, a cup of coffee as a drug) and enduring (such as, spinal injury or alcohol-induced memory deficits). In this section, we will focus on two issues: drugs and their effects, and separating the cortical hemispheres ('the split brain').

The Study of Drug Effects

Technically, a drug is any substance that has an effect on living cells. Since this could include virtually any substance, including water, we will use a more restrictive meaning of the term. *Drugs* are chemical substances which are foreign to the body, either totally or in the form introduced (for example, adrenaline is a hormone, but it may also be *injected* as a drug). It is worth noting that not all drugs are medically prescribed: a morning cup of coffee is an example of drug use (or abuse), as is the illegal use of cocaine. Also, not all drugs are of interest to psychologists, because they do not have discernible effects on *behaviour*. For example, penicillin reduces infections, but does not directly affect how we act. The study of **psychoactive** (mind-affecting) **drugs** is a concern in both psychology and medicine, and has given rise to a hybrid field called *psychopharmacology*.

psychoactive drug a chemical agent which has a discernible effect on mental state or behaviour.

The use of psychoactive drugs is probably as old as recorded history. Nearly every culture has used some type of fermented grain or vegetable to produce an alcoholic drink. Some South American tribes have long traditions of eating plants in order to alter perceptions as part of religious rites. But it is only relatively recently that doctors have considered the use of drugs as a therapeutic tool, or that researchers have had effective methods to study drug effects.

Psychopharmacology today has become a complex field, but in the early days of drug research, techniques were very pragmatic. Many psychoactive substances were first identified by studying plants which had already been used for folk remedies. For example, reserpine, one of the first tranquillizers, was originally isolated from Indian snakeroot; aspirin was isolated from willow bark. In other cases, researchers even explored drugs by experimenting on themselves. Heinrich Kluver, a man noted for his contributions in other areas of physiological research, wrote a paper on his experience with mescaline, a hallucinogenic drug derived from a type of mushroom (Kluver 1966). Today, research techniques have become more formal and sophisticated.

The methods typically used today for research on psychoactive drugs are much like those for other types of drugs. Typically, experimental animals are used to assess toxicity, strength and basis of effects. These assessments may involve intricate techniques and precision chemical analyses, such as injecting tiny amounts of the drug directly into specific regions of the brain, and then examining changes in neurotransmitter concentrations at nearby synapses. These methods often yield important information about the mechanism of drug actions, which is important to the preliminary screening of new drugs. Unfortunately, they do not provide sufficient information for a full understanding of drug effects.

Ultimately, psychoactive drugs must still be assessed by use on human subjects. There are several reasons for this: First, even the use of closely-related species like chimpanzees does not always produce the same results as with people. Second, even if the effects are the same, assessing them in animals can be difficult. By definition, the key aspect of psychoactive drugs is their effect on behaviour, which can include changes in alertness, responsiveness, mood, memory and even perceptions. Obviously, it is difficult to assess these effects in animals. This leads to the most basic problems in studying drugs: how to describe and categorize the effects.

By their nature, drugs operate on the physical system, yet the behavioural changes are primarily mental (perception, memory, etc.). This leads back to the problem of linking mind and body. Consider some of the possible difficulties:

1 Some drugs will affect only certain clinical groups, and not other types of patients or healthy individuals.
2 Some drugs affect sensory capacities in ways that are not directly expressed in behaviour. Consequently, even with verbal reports from subjects, it can be difficult to determine what is happening.
3 It is convenient to categorize drugs, but the categories may not always fit well with the subtleties of drug effects.

For example, the label 'antidepressant' focuses on one aspect of mood; however, drugs operate by affecting all neurons which have appropriate receptors, and this may involve much more than mood functions. The result can be a tendency to focus on an intended effect while overlooking various side effects. For example, many drugs used to treat schizophrenia do so by affecting a neurotransmitter called *dopamine*. While such drugs can often reduce delusional thoughts and hallucinations, they also can affect motor responses, which also depend on dopamine. In the end, it can be very difficult to match behavioural descriptions, which are partly based on culture, to the physiological effects of a drug, which depend on complex sets of neural pathways (Snyder 1980). These problems are not insurmountable, as the increasing sophistication of psychopharmacology shows, but they do present continual challenges to researchers.

In addition to understanding in what ways a drug alters behaviour, we need to understand how it operates in the body. In this regard, there has been tremendous progress in recent years. Essentially, all psychoactive drugs operate by affecting communication between neurons. As was described earlier, communication across the synapse is dependent on neurotransmitters. These chemical messengers are released by the terminals at the end of the axon, and flow across the synaptic gap to the receptors on the next neuron (see Figure 2.2). The relationship between the receptor and the neurotransmitter may be compared to a lock and a key – only a particular shape of neurotransmitter molecule will fit in a given receptor. (There are also variations on this basic theme. Sometimes, a molecule will seem to fit, but not influence the neuron; this is something like a key which fits a lock, but won't turn. By blocking the receptor site, such a chemical may prevent the proper neurotransmitter from reaching its target receptor. In other cases, chemicals attack neurotransmitters in the synapse, destroying them before they can reach the receptors.) While this lock-and-key metaphor applies to all neurotransmitters and psychoactive drugs, it was the basis for one of the great discoveries of modern psychopharmacology: endorphins.

The story begins with the study of opiates – a family of drugs which includes morphine, heroin and opium, all derived from the opium poppy. Although opiates have been used for hundreds of years (notably through the smoking of opium), the basis for their euphoric effects was unknown. As psychopharmacology developed, it became clear that drugs which affect behaviour must do so by affecting neural activity. This suggested that there might be a type of neural receptor which opiates activate. Based on this reasoning, a young researcher named Candace Pert began looking for opiate receptors in the brain. After several failures, she succeeded – the human brain did indeed have opiate receptors. Furthermore, comparative studies found that *many* species had such receptors – all the way down to the hagfish, which has existed essentially unchanged for 350 million years. This raised a new question:

why should a 350 million-year-old fish have receptors for a chemical derived from a flower? The only reasonable answer seemed to be that there must be a similar chemical which occurs naturally in the brain! Given that the opiate receptor sites which Pert found were located in regions of the limbic system and brainstem that are associated with pain and emotion, it suggested that the body may produce its own natural painkillers. The race was on to find such chemicals, and within a year, the search was successful. The first discovery was dubbed *enkephalin* (Greek for 'in the head'); shortly after, C. H. Li found what have become known as **endorphins** (for *end*ogenous – 'naturally occurring' – m*orphine* (Villet 1978). It was quickly recognized that endorphins were not typical neurotransmitters, but were rather small molecules called peptides. This prompted increased interest in such neuropeptides – chemicals which function as both hormones and neurotransmitters (see **Chemical Processes in Behaviour**, above). Subsequent research has found that, as Pert believed, endorphins play a role in pain relief, and may also mediate mood enhancement associated with exercise – so-called 'runner's high' (Hoffman 1997).

endorphin (endogenous – 'naturally occurring' – morphine) a neuropeptide which plays a significant role in pain and mood states.

The discovery of endorphins is like a detective story – finding clues, making deductions about what they mean and testing hypotheses until the solution is found. It also provides a good model for how drugs are discovered and evaluated today – by examining the molecular shape and matching it with receptor sites in the brain.

FOR FURTHER CONSIDERATION

If you were a researcher for a drug company, what kinds of psychoactive drugs would you want to search for? Drugs to relieve pain, depression or other disorders? Or would you focus on drugs to enhance intellectual performance and memory? Should drugs be used only to treat problems, or to enhance life? Why?

Types of Psychoactive Drugs

Advances in psychopharmacology have led to an increasing diversity of psychoactive drugs, and also to more widespread usage. At the same time, the frequency of their use has led to a change in social attitudes, so that drugs are more widely accepted, and in fact may be actively sought (studies suggest well over half of visits to doctors include writing a prescription – in part, because patients have come to see drugs as a cure-all). In addition to prescription drugs, there are a number of other drugs which have behavioural effects, but are often overlooked by consumers because of their non-prescription nature. For example, antihistamines, which are commonly used for the sinus problems of allergies, can also cause drowsiness – in fact, one common antihistamine, diphenydramine, is marketed as an allergy medication, and separately as a non-prescription sleeping aid! Given their pervasive presence in our culture, it is worth examining some commonly encountered drugs and their effects (see Figure 2.8 for a summary).

Psychoactive drugs are commonly divided into various categories, according to the general nature of their effects on behaviour (although, as noted previously, such categories are often imprecise). One category often overlooked in daily experience is the **stimulants**. Stimulants act on both the CNS and the autonomic nervous system (a portion of the peripheral nervous system that controls such functions as heart-rate and breathing, as well

stimulant a drug which increases activation of the CNS and the autonomic nervous system, typically by increasing levels of dopamine; these drugs tend to decrease fatigue, increase physical activity and alertness, diminish hunger, and produce a temporary elevation of mood.

Figure 2.8 Types of Drugs and their Effects – Sometimes drugs in the same category work by affecting the nervous system in different ways.

Type of Drug	Mechanism and Effects	Examples
Stimulants	Increase CNS activity—particularly by enhancing dopamine activity Increase alertness, suppress appetite, etc	Caffeine, nicotine, amphetamines, cocaine
Depressants	Reduce CNS activity—particularly by enhancing inhibitory effects of GABA Relaxation, sleepiness, etc.	Alcohol, barbiturates
Anti-anxiety drugs	CNS depressants—by reducing serotonin and norepinephrine effects and increasing GABA activity Lower anxiety; see also Depressants	Benzodiazepines: diazepam (Valium), lorazepam (Ativan), etc.
Antidepressants	MAO inhibitors—stimulate CNS amines (serotonin, norepinephrine, dopamine) by blocking enzyme for their breakdown SSRIs—enhance serotonin activity by blocking reuptake after release Dual-acting—enhance serotonin and norepinephrine activity by blocking reuptake Reduce depressed mood states	phenezine (Nardil) tranylcypromine (Parnate) etc. fluoxetine (Prozac) paroxetine (Paxil) etc. mirtazapine (Remeron)
Hallucinogens	CNS stimulants—various pathways depending on drug Enhance mood and perception; depending on drug and dosage, causes hallucinations	lysergic acid (LSD) mescaline MDMA (Ecstasy)—in large doses cannabis (marijuana)—in large doses

as general arousal level); in the CNS, they increase the activity in neurons which use *dopamine* as a neurotransmitter (Baldessarini and Tarzi 1996). (As noted earlier, dopamine affects a number of functions, including motor control and cognitive processes.) These drugs tend to decrease fatigue, increase physical activity and alertness, diminish hunger and produce a temporary elevation of mood. Both *caffeine* and *nicotine* are stimulants, although not as powerful as the prescription drugs known as *amphetamines*. Another stimulant, *cocaine* (often associated with drug abuse) is a stimulant which works by blocking the reuptake (reabsorption by the terminals) of dopamine, rather than mimicking its effects.(Volkow *et al.*, 1997). (See *antidepressants*, below, for discussion of a similar mechanism involving serotonin.)

Because stimulants tend to diminish hunger, amphetamines are sometimes prescribed as 'diet pills'. Smokers often experience a related effect when they reduce their smoking: the reduced nicotine level leads to an increase in appetite. Amphetamines are also sometimes prescribed for treating hyperactive children who show unusually high activity levels and an inability to concentrate; for reasons which are not clear, amphetamines seem to calm them down. Beyond these uses, stimulants have very few legitimate applications. They do not really reduce depression, nor are they a proper substitute for sleep when fatigued. Yet their use (and misuse) is widespread – sometimes users are even unaware, since stimulants like caffeine can be found in many common foods.

Caffeine is found not only in coffee, but also in tea, cola and chocolate bars. Children exposed to average amounts of cola and candy may be accustomed to caffeine long before they ever taste coffee. Nicotine, found in cigarettes, is also a stimulant. Although stimulants like caffeine and nicotine are treated casually in our culture, they nonetheless can cause adverse effects. With prolonged use, the nervous system tends to adapt to the presence of the stimulants. This can result in the phenomenon of *tolerance*, whereby one needs higher and higher doses to maintain the effect. In extreme cases, misuse of drugs can lead to *addiction*, which is determined by the occurrence of symptoms of physical *withdrawal*: when a person is addicted, stopping the drug provokes vomiting, muscle and heart tremors and seizures. (Note that addiction is *not* limited to stimulants – the pattern can arise with a variety of drugs.) While withdrawal symptoms to caffeine and nicotine are usually relatively mild, abuse of amphetamines or cocaine can be more serious. Chronic high doses of these drugs can lead to marked side effects, including hallucinations, delusions, and even a psychosis very similar to paranoid schizophrenia. (This phenomenon is one reason researchers believe that schizophrenia may be caused by excessive dopamine levels, as will be discussed in Chapter 9.)

depressant a drug which reduces CNS activity, by enhancing the effects of the neurotransmitter GABA; in large doses, depressants can cause coma and even death.

Curiously, individuals often confuse stimulants with **depressants**, which reduce CNS activity; in large doses, depressants can cause coma and even death. Among the well-known depressants are alcohol and barbiturates. People often regard alcohol as a stimulant, because in small doses it reduces inhibitions and increases talkativeness. In reality, these effects are due to differential sensitivity to the depressant effects by different parts of the brain. The 'higher' functions of the cortex are the first to be affected, which can lead to diminished self-consciousness and a reduction in learned inhibitions. In large enough quantities, alcohol (like other depressants) is a general anaesthetic, producing loss of consciousness. Over time, large doses of alcohol can also cause severe physiological effects, including memory deficits and liver damage.

Alcohol seems to enhance the effects of GABA, which is probably the most significant inhibitory neurotransmitter in the brain (see Fig. 2.6). Not only do about a third of all neurons in the brain have GABA receptors, but GABA can also directly affect axons, changing the threshold for firing. Alcohol's GABA-enhancing effects are similar to those of tranquillizers like Valium (benzodiazepine). This mechanism not only accounts for the anti-anxiety effects of alcohol, but may also explain reported claims of tolerance and dependence for the benzodiazepines (Smith 1992).

Abuse of alcohol may well be endemic in our culture: it has been estimated that 5 per cent of the population in both the USA and Canada have a serious drinking problem, and alcoholism is a problem in virtually all countries (Helzer and Canino 1992). No one is certain whether alcoholism is based on a physiological malfunction or is based on learned drinking patterns. There is evidence that it runs in families, but this may mean either that there is a genetic cause, or that the children learn patterns from their parents. In either case, most treatments show only limited rates of success and alcohol may well be our largest drug problem.

anti-anxiety drug a drug which functions as a CNS depressant, but whose primary behavioural effect is the reduction of anxiety.

The difficulty in creating descriptive categories for drugs is highlighted when one considers **anti-anxiety drugs** or tranquillizers. While their general effect is based on being CNS depressants, they have broader effects than alcohol and other simple depressants. That is, although they enhance the activity of the inhibitory neurotransmitter GABA, they also reduce activity of *stimulatory* neurotransmitters (primarily serotonin and to some degree, norepinephrine), which alcohol does not (Langen *et al.* 2002). The most common anti-anxiety drugs are the benzodiapines, such as Valium or Ativan. As a result of their broader action, benzodiazepines are more effective at reducing anxiety than is alcohol, but this advantage does not come without a cost: a serious problem with these drugs is their tendency to be addictive, with withdrawal symptoms occurring when discontinued after long periods of use. They have also been linked to the occurrence of depression – an effect which is understandable when we look at the nature of antidepressant drugs.

antidepressant a drug which is used to treat clinical depression, primarily by enhancing the activity of the neurotransmitter serotonin.

Antidepressant drugs are used to treat severe clinical depression, which is characterized by low mood state, fatigue and feelings of hopelessness. Early antidepressant drugs, called *MAO inihibitors*, blocked the enzyme monoamine oxidase, an enzyme which breaks down several stimulatory neurotransmitters, including serotonin, norepinephrine and dopamine. Unfortunately, this often created a variety of adverse side effects, which is not surprising given the many ways that these neurotransmitters are used in the brain. More recently, a new class of antidepressants has been developed, called SSRIs (selective serotonin reuptake inhibitors). As the name implies, their effect focuses on neurons which use serotonin. Rather than simply mimicking serotonin, they enhance the effects of serotonin by delaying its reuptake by the terminals of the neurons which released it. Not surprisingly, SSRIs (such as Prozac) tend to have fewer side effects than the MAO inhibitors, since they do not significantly affect the functioning of norepinephrine or dopamine. The difference between the two classes of antidepressants is a good example of how pharmacologists are seeking to develop drugs with more specific effects. Interestingly, recent research suggests that drugs which enhance norepinephrine as well as serotonin (such as mirtazapine) may be more effective than SSRIs, while reducing the side effects associated with MAO inhibitors (Schatzberg 2002). In all likelihood, as our understanding of the processes underlying depression continues to improve, so will the effectiveness of drugs.

The linkage between low levels of serotonin and depression can also help us to understand several other phenomena. For example, it helps explain why benzodiazepines, which reduce anxiety in part by reducing serotonin activity, have been implicated in depression. It also helps to understand the effects of a street drug, MDMA (often called 'Ecstasy' or 'E'). MDMA seems to work by triggering a massive release of serotonin – hence, its primary effect is to stimulate CNS regions involved with mood and perception. Like any illegal drug, its actual composition depends on the producer, so its nature and purity is often uncertain, along with its effects. What is known is that the artificial cascade of serotonin caused by pure MDMA is followed by significant depletion of serotonin, resulting in a short-term 'down' after use. With regular use, MDMA appears to increase the risk of depression, and some studies suggest that it has long-term effects on the nervous system (Parrott 2001).

While by no means exhaustive, the preceding discussion should demonstrate that psychoactive drugs, both prescription and non-prescription, are extremely common. Their prevalence often lulls people into thinking they are harmless, yet chronic, casual use of drugs can be a danger in many ways, and as noted, prolonged use can lead to tolerance and addiction. In other cases, side effects may be infrequent but severe (for example, Prozac can severely suppress appetite in some individuals; at one time, its manufacturer considered seeking certification for its use as a diet pill.) Another potential problem can arisefrom the interaction of a drug with other drugs or even certain foods. For example, barbiturates (a depressant) can interact with alcohol (also a depressant) in a *synergistic* manner – that is, the effect of the two together is greater than for either alone. (Marilyn Monroe died from a combination of alcohol and barbiturates.) Synergistic interactions may also occur between drugs and non-drugs, such as food: some cheeses, such as Blue or Roquefort, can be dangerous or even lethal if consumed while taking certain drugs.

Our knowledge of synergistic effects is limited at present, and undiscovered combinations may exist. Unfortunately, casual attitudes towards drugs may cause people to underestimate the possible risks. For the present, the best approach seems to be caution: never take a drug without reason, and then only under a doctor's supervision. Always tell a doctor if you are taking medicines which have been prescribed by another doctor. If you take a drug, watch for drowsiness or other side effects that may impair your ability to deal with your surroundings.

Drugs which affect mood or behaviour are not new, nor are the circumstances that lead people to use them, such as seeking relief from anxiety. However, our understanding of the mechanism of such drugs is growing. The methods of research are becoming more sophisticated, and with them our ability to use drugs as a therapeutic tool. While no amount of research can ever determine social attitudes, ideally such attitudes are based on knowledge. To this end, the next few years offer hope of great strides in our ability to understand the role of drugs in mind–body interactions.

FOR FURTHER CONSIDERATION

If you use caffeine (found in coffee, tea, colas and chocolate) or nicotine (found in tobacco), you might consider whether you notice any effects the next time you ingest the drug. If you don't notice any effects, could this mean you have developed a *tolerance* for the drug?

The Split Brain and the Whole Mind

According to the materialist view, consciousness must have a physical basis, most probably in the brain. The problem for researchers has been to find a way of identifying it. While research has produced support for the principle of localization of function, it still has not answered the question: where is the mind?

Normally, our experience of the world, reflected in our inner thoughts and feelings, seems unitary – that is, we have only a single consciousness. Yet the structure of the brain, especially the cortex, is basically two symmetrical halves. These halves, made up of the cortex and underlying structures, are called the **cerebral hemispheres**. Connecting the two hemispheres is a wide band of nerve fibres called the **corpus callosum**. Researchers have long known that each hemisphere is basically responsible for the opposite side of the body (for example, your left hemisphere receives sensations from, and gives motor commands to, the right side of your body). Now, if consciousness is really associated with the cortex, then it implies that the unitary nature of our experience and awareness is based on the integration of the two hemispheres. This reasoning led pioneering psychologist Gustav Fechner to speculate, more than one hundred years ago, that if the two hemispheres were somehow separated, we would have *two* separate consciousnesses. Fechner never thought that this could be tested, but time has proven differently.

cerebral hemispheres two half spheres, made up of the cortex and underlying structures, which comprise the major portion of the brain.

corpus callosum a wide band of nerve fibres which connect the two hemispheres.

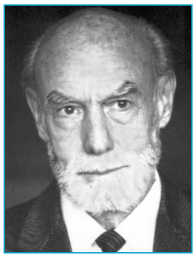
In the 1950s psychologist Roger Sperry, working with monkeys, suggested that separating the two hemispheres by cutting the fibres of the corpus callosum, had no grave effects on behaviour – certainly less than procedures like *frontal lobotomy*. Still, this gave no indication of what might happen in humans. One obvious difference between primates and people is that monkeys do not speak, and Broca had shown that speech was found in only one hemisphere. Consequently, no one was sure what would happen if the hemispheres were separated in a person.

The question was answered in the course of dealing with a more immediate medical problem. In the 1960s, a Los Angeles surgeon Philip Vogel was trying to treat patients with a long history of epilepsy. While in many cases epileptics could be treated with anti-seizure drugs, these patients did not respond to drug treatment; consequently, they had major seizures, on average, twice a week. In epilepsy, the random neural activity of a seizure usually starts at a point in one hemisphere and spreads, creating sensory distortions and convulsions. In cases of grand mal attacks, the seizure activity spreads from one hemisphere to the other across the bridge provided by the corpus callosum. In such cases, the recurring seizures can disrupt normal life, and even present a life-threatening situation. When all other treatments failed, Vogel tried a new and radical approach: By cutting the fibres of the corpus callosum, he hoped to restrict the seizure activity to one hemisphere, and thus prevent grand mal attacks. While he knew of Sperry's work, and there had been occasional clinical reports of damage to the corpus callosum, no one had ever purposely separated the hemispheres before. Vogel and his patients were venturing into new territory.

Medically, the treatment worked. Not only did it prevent further grand mal attacks, but (for reasons still unclear) it also reduced the frequency of more limited seizures. At the same time, it was desirable to know what negative effects, if any, the surgery had caused. Knowing of Sperry's research, Vogel asked him to collaborate on evaluating the patients. The results were a surprise to all concerned.

Initial observations suggested that the patients were remarkably normal. Everyday actions like walking and eating seemed to occur naturally. However, by a series of ingenious testing procedures, Sperry, Vogel and their associates discovered that, in fact, these individuals had an unusual mental syndrome. As Sperry reported, 'Instead of the normally unified single stream of consciousness, these patients behave in many ways as if they have two independent streams of conscious awareness, one in each hemisphere, each of which is cut off from and out of contact with the mental experience of the other' (Sperry 1968, p. 724). In other words, *two* minds, each functioning separately from the other – Fechner's prediction had been correct! (Ultimately, Sperry's research on the split brain led to his receiving the Nobel Prize in physiology in 1981.)

ROGER W. SPERRY



Roger Walcott Sperry (1913–) is an American neurological researcher who pioneered much of our understanding of hemispheric specialization. His career began relatively slowly, and he received his doctorate in zoology at the University of Chicago at the age of 28. While there, he worked with the biophysicist Paul Weiss, studying how the connections between neurons and muscles are formed. This led to further work on the regeneration of neural connections between the retina and brain in amphibians. While doing this work, he met biologist Norma Dupree, with whom he collaborated; they married in 1949. In 1952, he moved to the California Institute of Technology, where he remains a professor emeritus of psychobiology. In 1953, one of his graduate students, Ronald Myers, invented the split-brain procedure, the study of which later led to Sperry's most important discoveries; ironically, Myers's initial role is seldom cited in this regard. They first studied the effects of severing the corpus callosum in cats and primates; however, it was Sperry's later work on epileptic patients, in collaboration with neurosurgeon Joseph Bogen, that eventually led to Sperry sharing the 1981 Nobel Prize in Physiology or Medicine. Sperry's contributions continue to be carried further by his students, including Jerre Levy and Michael Gazzaniga.

To assess the effects of the surgery, the researchers had to use techniques whereby information was presented to only one hemisphere. The simplest case involved touch: if the split-brain person were given an object in their left hand while blindfolded, the left hand could later pick it out again, by touch, from a selection of several objects. However, if the right hand attempted to pick out the article previously held by the left hand, it did no better than chance. In the case of vision, the situation is a bit more complicated, because each eye is connected

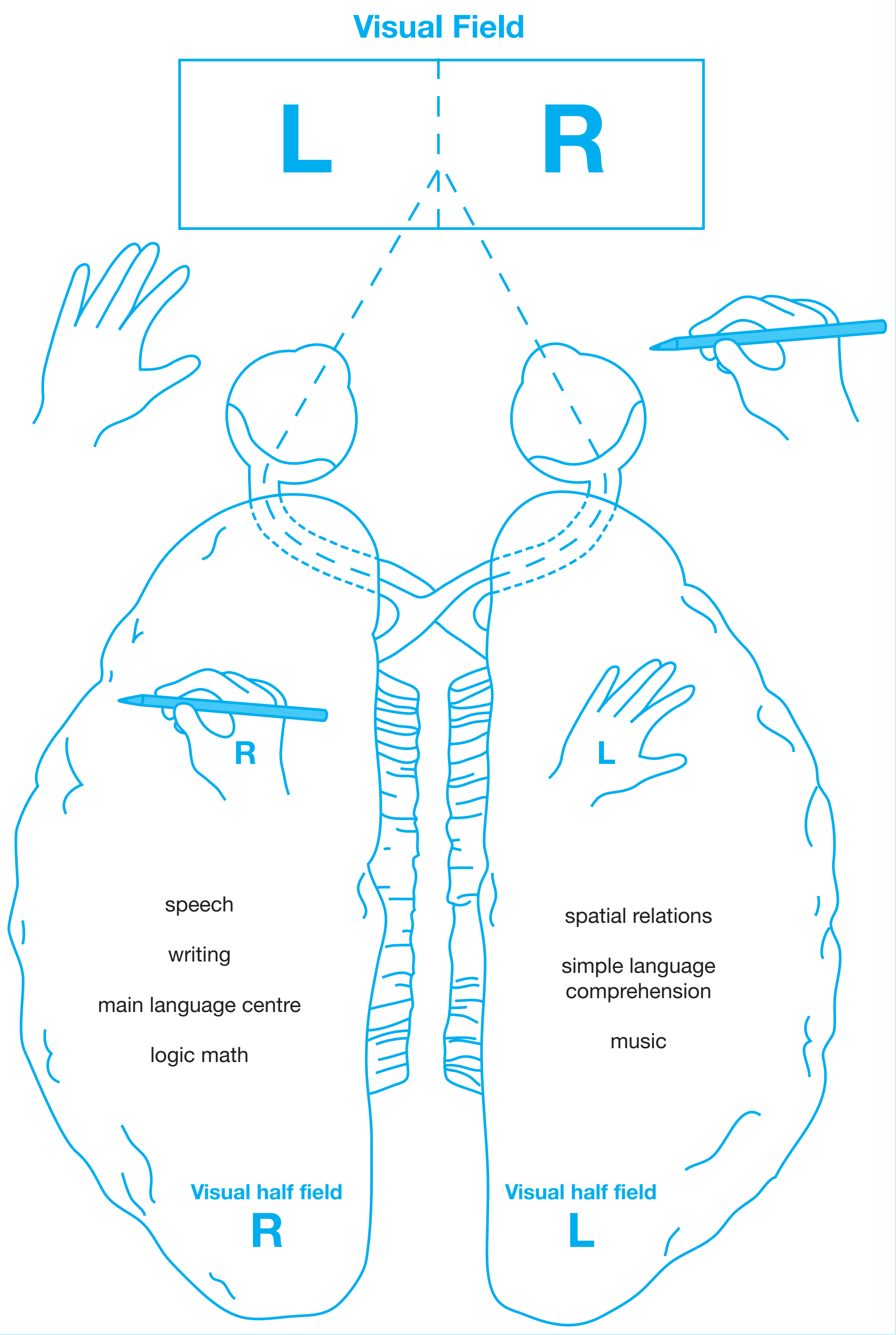


Figure 2.9 Hemispheric Specialization – Roger Sperry's work with split brain individuals (note the cut fibers of the corpus callosum between the hemispheres) has helped to identify differences in the functions of the two sides of the brain. (After Sperry 1968)

to *both* hemispheres. The division of visual processing is such that the visual world of each eye is divided in two, so that objects on the left side of the visual world (or *visual field*) are seen by the right hemisphere, while objects on the right side are seen by the left hemisphere, regardless of which eye is used (see Figure 2.9). Thus, if a person looks straight ahead and an image briefly appears to the left, only the right hemisphere receives the information. In Sperry's research, this procedure led to an interesting discovery: Because only the left hemisphere had language, a split-brain person presented with a word or picture on the left side (conveyed to the right hemisphere) could not say what they had seen! Only the left hemisphere seemed able to talk, while the right was silent (note, of course, that these effects only apply when the corpus callosum has been cut; in a normal individual, there is continual exchange of information between the two hemispheres).

As it turns out, the differences are not quite what they first seemed. The right hemisphere, while usually unable to speak, is not completely ignorant of language. If presented with a word or picture, it can point to a corresponding picture or word. Thus, if the right hemisphere sees the word 'key', the left hand can correctly choose a key. At the same time, the right hemisphere has musical and spatial abilities which seem to be lacking in the left hemisphere. If given geometric figures to copy (such as a circle overlapping a square), the left hand (right hemisphere) does a better job of copying it than does the right hand (left hemisphere). This is particularly striking, since the patients Sperry tested were all right-handed, so in principle one might expect the right hand to be more skilled. For handwriting, the right hand *is* better; for drawing, it is not. This raises a fascinating problem: since lettering is a type of artistic skill, why is it that the left hand, so superior for other drawing tasks, is poor at reproducing letters and words? So far, this aspect of the split-brain phenomenon has not been fully explored.

Despite the apparent handicap and dual-consciousness which they possess, split-brain individuals manage to cope very well in everyday life. Even tasks requiring motor coordination of the two hemispheres, such as riding a bicycle, can be mastered. Over time, it even seems that indirect methods of communicating between the two sides develop. For example, in one experiment, Sperry flashed either a red or green card to the left visual field (right hemisphere), and then asked the person to name (left hemisphere) the colour. As expected, the left hemisphere, not having seen the colour, did poorly. However, if allowed to reconsider, the person was always correct. What seemed to happen was that the right hemisphere, hearing the spoken response of the left hemisphere, would produce grimaces and other gestures if the answer was wrong. These cues let the left hemisphere know its error, which it then corrected!

Since Sperry's original research, a large number of studies have been done, even though the number of split-brain individuals is quite small (between 1962 and 1968, Vogel operated on a total of nine patients). Overall, the results have supported Sperry's original work, although it is now recognized that the differences between the hemispheres are not absolute (Trevarthen 1987). Still, the research does suggest several things:

1. If the corpus callosum is cut, the two hemispheres function independently.
2. Each hemisphere seems to possess consciousness, but without awareness of the other. (In one case, a patient, seeing her left hand make a response, exclaimed, 'I didn't do that!').
3. The two hemispheres seem to show different types of specialized abilities, with the left hemisphere usually possessing language, logic, and math skills, and the right hemisphere spatial and musical skills.

There is also evidence that there is specialization in terms of emotion, with the left frontal lobe involved in processing positive emotions, and the right frontal lobe involved in negative emotions (Davidson and Irwin 1999).

The Split Brain and the Normal Brain

The striking nature of the split-brain findings makes it tempting to extend the conclusions to normal individuals. At the same time, it must be recognized that severing the corpus callosum is not a natural condition, and normally the two hemispheres communicate freely. Still, research seeking to test these findings in normal individuals does indicate that the two hemispheres tend to become specialized in ways similar to what has been observed in split-brain individuals. For example, clinical cases show that damage to the left hemisphere, whether by disease or trauma, can impair speech. However, one should be careful about over-generalizing. For one thing, it should be noted that in a small percentage of people, primarily left-handers, the pattern of hemispheric specialization is modified or reversed. Also, the degree of specialization for language may depend on what language an individual speaks – language processing may differ for native speakers of Chinese, which uses pictographic characters rather than an alphabet. Recent research using fMRI imaging demonstrates there is activation in both left *and* right hemispheres when Chinese speakers read, and the way language is processed in the left hemisphere differs from the pattern for English speakers (Luke *et al.* 2002); and it is not just language which shows variations. While Sperry found that musical ability was normally associated with the right hemispere, studies indicate that when professional musicians listen to music, the *left* hemisphere is actually more active; in effect, musicians seems to process music as if it were a language (Schlaug *et al*. 1995). Research has also suggested that there may be gender-related differences in the pattern of hemispheric specialization. A variety of studies indicate that language is less lateralized in women (that is, both hemispheres are involved), and that men are superior in spatial tasks (Gazzaniga *et al*. 1998; Kimura 1999; Phillips *et al*. 2001). Hence, while the general notion of hemispheric specialization seems valid, there can be variation in the details.

cerebral dominance the tendency for one hemisphere to be superior for particular functions, as expressed through behaviours like handedness.

One issue that has arisen out of split-brain research is an increased interest in **cerebral dominance** – the tendency for one hemisphere to be superior for particular functions. In most individuals, one hand, foot, eye and ear are usually preferred for many actions – for instance, if standing, we begin walking with the dominant foot. Similarly, if using a camera or telescope, we usually focus with the dominant eye. Such preferences have been noted since ancient times, and the origin of cerebral dominance has caused much speculation among researchers. Evidence suggests that dominance, as seen in preferences for one side, is already developing at birth.

Handedness, which is the most visible indicator of dominance, has often been the focus of social prejudice. In many languages and cultures, being left-handed is viewed negatively. This can be seen in the way we use words: A 'left-handed compliment' is not really a compliment. To be 'right' is to be correct. A suspicious person is 'sinister' (Latin for left-handed), while a skilful person is 'dextrous' (Latin for right-handed). Similarly, a 'gauche' (French for left) remark is in bad taste. These usages reflect a form of cultural bias, and lead to questions about the origin of handedness, and dominance more generally.

Theories of the origin of handedness cover a broad range, including genetic factors, prenatal learning (position within the womb) and congenital brain damage (left-handedness being the result of such damage) (Corballis 1997; Coren 1995; Previc 1991). At present, there is no conclusive evidence for any of these theories. While it is known that dominance is somehow related to hemispheric specialization (for example, stuttering in adults correlates highly with forcing right-hand use on a left-handed child), no one is sure exactly what the connection is. Attempts to alter dominance do seem to have some impact on skills like language, but that does not prove that dominance is the source of specialization. In fact, the *pattern* of hemispheric specialization seems much the same in both left- and right-dominant individuals (although left-handers are slightly more likely to show a reversed or mixed pattern of hemispheric specialization). In addition, there is no proven explanation as to why right-handedness (dominant left hemisphere) is the norm across races and cultures. Like many aspects of brain function, there are still many unanswered questions about handedness, dominance in general and hemispheric specialization. Even so, most researchers would agree that, despite social prejudices, one should not interfere if a child shows a preference for being left-handed.

The research on the split-brain and cerebral dominance brings us back to our initial questions: is localization of function correct, and does consciousness reside in the brain? The research on split-brain individuals seems to indicate that consciousness involves the cortex, for separating the cerebral hemispheres seems to split consciousness as well. However, since it involves such a large-scale division, it offers us very little information in terms of determining precisely where consciousness resides. After all, the hemispheres each involve cortex, underlying sub-cortical tissue, limbic system structures, and so on, down into the brain stem, spinal cord, and beyond. To say that the two sides of the body can each have their own consciousness does not tell us what sort of structure *produces* consciousness. A materialist view which assumes localization of function would argue that we should be able to find some specific neural circuit that represents conscious awareness. At present, no study has found such a circuit; current attempts to do so tend to limit themselves to particular *aspects* of consciousness, such as visual awareness or attention (Blanke *et al*. 2002; Crick and Koch 1992; Newman 1995). Similarly, a recent case study reported stimulating changes in bodily awareness (including 'out-of-body' experiences) by using Penfield's procedure (Blanke *et al*. 2002). So where does this leave us in trying to identify the origin of consciousness?

The lack of evidence for a single circuit representing general awareness has led various researchers to take different points of view. In a book written shortly before his death, Penfield noted the absence of any evidence for the localization of consciousness. Consequently, he concluded that consciousness was not a function of the brain, and he essentially reverted to a form of dualism (Penfield 1975). Sperry, by contrast, simply rejects the idea that consciousness is localized, without abandoning materialism. He views consciousness as an *emergent property* of the brain (that is, a phenonemon which emerges from the system working as a whole), and suggests that no study of individual parts will enable us to pin it down (Sperry 1969). This view is supported by a French EEG study which found that the moment of recognition of an ambiguous visual image was marked by synchronized activity across many areas of the brain (Rodriguez *et al*. 1999). Neurologist Antonio Damasio goes even further than Sperry, arguing that the mind is a product of the entire organism, operating as an ensemble (Damasio 1999). In his view, not only the brain must be considered, but also its links to the rest of the body; severing any of these links would also change the mind. Thus, to go back to the 'brain in a vat' question raised earlier, Damasio would say a brain removed from the body could never function as a normal mind. At present, all these views are ultimately speculative, but current data suggest both that there *is* localization of some functions, *and* that the nervous system works as a coherent unity. In this sense, it may well be that the mind is connected to the body – but we may never be able to fully describe the relationship.

FOR FURTHER CONSIDERATION

Are you left- or right-handed? Consider the types of skills that are associated with each hemisphere. Do you see any relationship between your own dominant hemisphere and your relative abilities? (Remember, the preferred hand is associated with the *opposite* hemisphere.)

The Effects of Mind on Body

'Mind over matter'. The phrase has been used to describe many things, from accomplishing a difficult task to claims of levitation. The most common meaning is to describe how physical reactions are seemingly altered by mental processes. The view that this is paradoxical or impossible can be traced to Descartes' dualistic conception of mind and body, in which the mind has no physical basis. In this sort of framework, it becomes difficult to imagine how mental states could affect specific body functions. By contrast, in a materialist framework, where mind and body are linked, it becomes easier to conceive of such interactions. 'Mind' and 'brain' may represent different levels of description, but materialism assumes that they have a common physical foundation.

This unified view can help us to understand what would be otherwise inexplicable phenomena. A common example is the reaction to painful stimuli: Everyday observation demonstrates that people react differently to similar physical traumas. To one person a trip to the dentist may be terrifying, whereas to another it is no more painful than scratching an itch. Such variations can occur across cultures as well. In Western culture, childbirth is usually regarded as an intensely painful experience, but not by members of some other cultures (Melzack 1973). Similarly, the Sherpas of Nepal are noted for their stoic response to the gruelling conditions of mountain-climbing (Clark and Clark 1980). Thus, response to painful stimuli seems to show considerable variation. Pain researcher Ronald Melzack believes that such variations in pain are due to differing cognitive expectations and perceptions, a view supported by clinical research (Haythornthwaite *et al.* 1998). Since cognitive processes (including perception and attitudes) are regarded as functions of the cortex, Melzack's theory says that the effect of expectations on pain response is mediated by cortical influences. Phantom limb phenomena, as mentioned in the introduction, may also be the product of the way the person interprets sensory inputs, rather than an automatic response (Melzack 1992). Such phenomena give new meaning to the phrase 'mind over matter', by suggesting that mental states can influence physical functioning and behaviour. In this section, we will consider research related to two issues that highlight these interactions: the effects of stress, and relationships between mental states and health.

The Nature of Stress

Like pain, stress is a common human experience. We are all familiar with stressful events: your heart races as you sit down to write a test; or the boss wants to see you *now* about the last quarter's sales figures; or you go to bed, only to hear the neighbour's stereo blaring away. The pulse-pounding, gut-wrenching sensations that result from such moments are common in modern life. When we recognize the feelings, we may experience the desire to run away to a desert island. Unfortunately, even this may not solve the problem of stress.

stress a term coined by Hans Selye to describe the non-specific response of the body to any demand on it.

According to Hans Selye, the doctor who pioneered stress research, **stress** is the non-specific response of the body to any demand on it (Selye 1978.) Interestingly, what first led Selye to the study of stress was an observation he made as a second-year medical student in 1926. As part of their clinical training, the students encountered patients suffering from a variety of disorders, and Selye noted that 'they all looked sick'. His professors and fellow students laughed at his suggestion that disease, no matter what its nature, could produce certain consistent changes. Some ten years later, as a medical researcher, Selye returned to this question, and named the syndrome 'stress'. The term, borrowed from physics, was meant to refer to the effects of resisting an outside force (Selye 1978).

HANS SELYE

Hans Selye (1907–82) was born in Vienna, Austria in 1907. He was educated in Prague, Paris and Rome, entering medical school when he was 18. He eventually earned three doctorates (MD, PhD, and DSc), though primarily he was regarded as an endocrinologist (a doctor specializing in hormone functions). He began his pioneering research in the 1930s, and coined the term 'stress' in a 1936 paper. (Subsequently, lectures in France and Germany led to coining *le stress* and *der Stress*.) World War II led to him moving to Canada, where he became a professor at the University of Montreal and first director of the Institute of Experimental Medicine and Surgery. During the course of his career, he published over 30 books and more than 1,500 articles on stress and related subjects. Whereas his first observations of stress-related phenomena (while still a medical student) were greeted with scepticism, over time his research became widely acknowledged, and he was the recipient of many scientific honours, including 43 honorary degrees. After retiring from the University of Montreal, he founded the Canadian Institute of Stress in 1979. He died in Montreal on 16 October 1982.

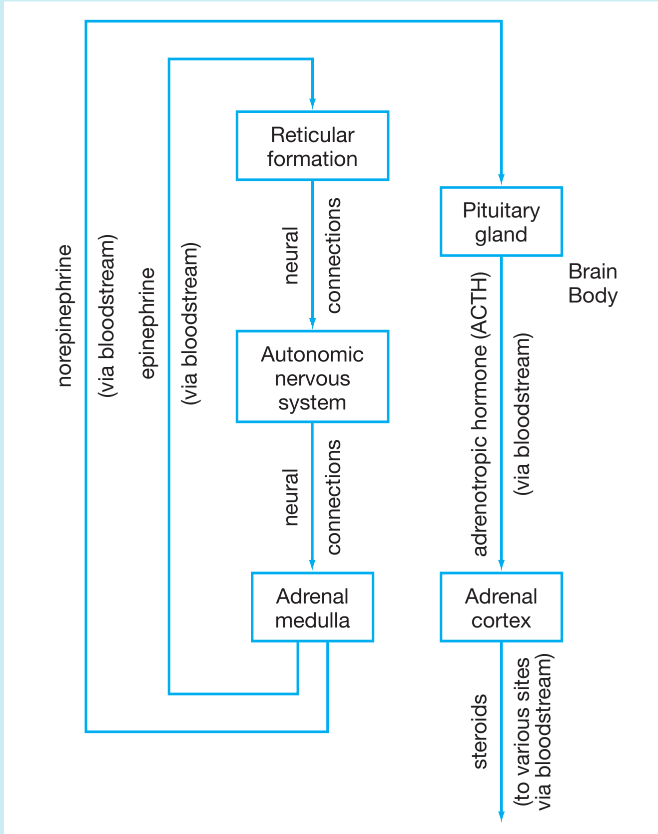
As Selye noted, stress occurs as a response to a range of circumstances. Biologically, stress reactions evolved as an emergency response intended to prepare an individual for 'fight or flight' – that is, either to defend oneself or try to run away from a threat (essentially the same pattern of reactions can be found in all mammals). In psychological terms, stress is a response of the body to whatever is perceived as an emergency situation. However, not all situations that trigger stress are alike, and under some circumstances what evolved as an adaptive mechanism can be potentially harmful. To understand this, first consider what happens when one experiences stress.

adrenal glands endocrine glands, located just above the kidneys, which play an important role in arousal and stress; the outer layer, the cortex, secretes corticosteroids, and the medulla (the inner core) secretes adrenaline (epinephrine) and noradrenaline (norepinephrine).

A significant link in the body's chain of reactions to stressful situations is the release of hormones by the adrenal glands. The **adrenal glands**, located just above the kidneys, are made up of two portions, the *cortex* or outer covering, and the *medulla* or inner core. When stimulated, the adrenal medulla secretes *adrenaline* (also called epinephrine) and *noradrenaline* (norepinephrine). Each of these hormones plays a role in stress reactions. (As noted earlier, the same chemicals also function as neurotransmitters.)

The release of adrenaline into the bloodstream produces reactions in both the brain and the peripheral nervous system. In the brain, it increases activity (particularly in the reticular formation, which controls overall arousal). In turn, the reticular formation sends signals to the autonomic nervous system (a branch of the peripheral nervous system), which shuts off digestion, increases heart rate, and raises blood pressure, among other reactions (see Figure 2.10). Since the adrenal glands are among the organs affected by the autonomic nervous system, the overall sequence of responses is a 'closed loop'; the circular nature of the

Figure 2.10 **A Schematic Diagram of the Body's Response to Stress –** Stress reactions involve a series of effects involving an interaction of the nervous system and the hormonal system. Note that the response involving epinephrine is a 'closed loop', which tends to be self.maintaining in the absence of off.setting interventions by the parasympathetic division of the autonomic nervous system.



pituitary gland a small gland adjacent to the hypothalamus which regulates many endocrine functions, including growth, and also interacts with the nervous system via hypothalamic connections; in stress, it releases a hormone called ACTH which triggers the release of steroids by the cortex of the adrenal glands; sometimes called 'the master gland' because of its many functions.

steroids hormones produced by the cortex of the adrenal glands which are involved in the regulation of water and sugar metabolism, immune system function, and other basic bodily processes; sometimes called 'corticosteroids'.

sequence means that the stress reaction produced by adrenaline can be prolonged. Anyone who has been startled or has otherwise experienced sudden stress knows that the racing heartbeat and other signs can linger beyond the moment of stress.

As mentioned above, noradrenaline also plays a role in stress reactions, but its function is more indirect. Travelling through the bloodstream, it reaches the brain, where it activates another gland, the **pituitary**, which in turn releases another hormone, ACTH (adrenocorticotropic hormone). ACTH in turn reaches the adrenals, causing the adrenal cortex to produce hormones called steroids. (Note that the adrenal *medulla*, not the *cortex*, produces noradrenaline and adrenaline.)

Steroids (sometimes called 'corticosteroids') play a role in a diverse range of body processes, both at times of stress and in daily living. They are involved in the normal regulation of water and sugar metabolism, including the quick release of sugar for energy under stress. They also affect the immune system, including inflammatory response. Among the most significant of these steroids is *cortisol*; a synthetic form of this steroid, cortisone, is used in medicine for treatment of allergic reactions, arthritis and shock.

While this description may seem to emphasize the role of hormones, and particularly the adrenal glands, the changes associated with stress are actually a complex sequence involving many body systems, as noted above. Selye described the overall pattern as the **general adaptation syndrome** of stress, involving three stages. He called the initial, acute stress response (described above) *alarm*; essentially, it is equivalent to the fight-or-flight response described above. If the stress continues, there is a second stage, *resistance*, where the organism seems to be coping with the stress, and *outward* signs of arousal disappear;

general adaptation syndrome a model of stages of stress identified by Hans Selye, ranging from acute stress (alarm) to outward coping (resistance) to finally depletion of bodily resources (exhaustion).

internally, increased hormonal production, etc. continues. If the situation persists, Selye argued that the final stage, *exhaustion*, may be reached, where the body's resources are depleted; in studies with experimental animals, this has resulted in sickness or death. Autopsies on these animals reveal enlarged adrenal glands, severe ulcers of the stomach, and shrinkage of the thymus gland and lymph nodes, which are involved in the body's immune system.

The stress response originated as a means of coping with physical danger, and its evolutionary survival suggests the mechanism is basically adaptive. However, it also creates two major problems. First, for modern humans the 'danger' may often be psychological rather than physical (for example, pressure to meet a deadline), and hence no physical response is either required or appropriate. This means that one is left with a surge of activity-oriented chemical changes, and no outlet for the energy. Second, as Selye noted, the stress response may carry beyond the moment of crisis, and chronic stress can have negative effects (for either people or animals). Consistent with Selye's early description of the effects of prolonged stress, a wide range of disorders, including heart disease, viral infections, asthma, and rheumatoid arthritis, seem to be affected by stress responses (Everly and Lating 2002; Heninger 1995; Krantz *et al.* 2000; O'Leary *et al.* 1997). To a large degree, these effects are related to hormonal changes, particularly the excess production of steroids. For example, elevated levels of cortisol have been associated with both depression and memory problems (Newcomer *et al.* 1999; Pruessner *et al.* 2003; Wolf *et al.*

Figure 2.11 The Holmes-Rahe Social Readjustment Rating Scale

A Barometer of Stress

Stressful experiences can have great impact on a person's ability to function. But what are stressful circumstances, and what types of experience typically cause the greatest stress? A long-term study by Rahe, referred to in the text, attempted to answer these questions by looking at the effects of various events on the probability of becoming ill. Generally, the effects were found to be additive—that is, people who went through more life changes were more likely to get sick. High stress levels seem to impair the body's ability to function.

A look at the table below will show you the estimated stress value of various events. Rahe suggested that if your stress total went above 150 for any twelve-month period, you were in a high-risk group, and should heed the storm warnings of the stress barometer.

Rank	*Life Event*	*Stress score*
1	Death of spouse	100
2	Divorce	75
3	Marital separation	65
4	Jail term	63
5	Death of close family member	63
6	Personal injury or illness	53
7	Marriage	50
8	Fired from job	47
9	Marital reconciliation	45
10	Retirement	45
18	Change to different line of work	36
25	outstanding personal achievement	28
27	Begin or end school	26
32	Change residence	20
40	Change in eating habits	13
41	Vacation	13
43	Minor violations of the law	11

Adapted from Rahe 1972

2001). While researchers are beginning to understand the underlying mechanism of these effects (see Mental States and Health), a more immediate question is what *triggers* chronic stress.

The pioneer for such studies was a psychiatrist named Thomas Holmes, who in the late 1940s became interested in the effects of major life changes on the health of his patients. He examined the case histories of more than 5,000 patients, and developed a 'stress barometer' of life changes now known as the Social Readjustment Rating Scale (see Figure 2.11). Later, Dr Richard Rahe used Holmes's work as the basis for a study of 2,500 men in the US Navy. Using the stress scale as a predictor of illness over a twelve-month period, he found that those who underwent the highest number of life changes suffered nearly twice as many ailments as those in the lowest category (Rahe 1972). Subsequently, the value of life-changes as an indicator of stress has been supported in other studies (e.g., Brown and Harris 1989). One study followed laid-off Finnish workers over several months, and found high rates of depression and stress-related illnesses (Viinamaeki *et al.* 1996).

Despite such results, critics have raised a number of problems, the most basic being that the research is correlational, and so cannot prove that the indicated life changes are the causal factor. Beyond that, there are questions about the specific types of events that the scale measures – for example, whether positive changes are as damaging as negative changes, and whether major life changes are really more stressful than encountering many minor hassles (Everly and Lating 2002). The life-change scale continues to be popular (in part because it provides a quick and simple tool for clinicians), but understanding the dynamics of stress requires looking more closely at individual factors. Doing so will also provide some understanding of how to deal with stressful situations.

Coping with Stress

As should be clear, the basic fight-or-flight response that underlies stress has been programmed by our evolutionary history. But what triggers that response? Although Holmes and Rahe focused on life changes as a source of stress, defining what is a **stressor** can in fact be difficult. Life-threatening situations by their nature create stress, but individuals will sometimes react to more minor situations (like a traffic jam) with the same fight-or-flight response. In general, the degree of stress experienced depends not only on the situation, but also on one's perception of the situation and one's mode of response (Endler 1997).

stressor any factor which triggers a stress response in an individual.

The individual's interpretation of the situation may in fact be the most important determinant of the effects of 'stressful' situations. As was discussed in Chapter1, individuals perceive any situation in terms of their own cognitive schemata. For example, a person who has been thinking of making a career change may welcome an offer of early retirement, whereas a person content in their job may be very upset at a similar offer. Similarly, diving into cold water may sound stressful, yet every New Year's Day members of 'polar bear clubs' willingly jump into icy lakes or oceans. Thus, our *cognitive appraisal* of the situation is a key factor in determining whether, and to what degree, we experience a situation as stressful. Because the processes that underlie perception are embedded in the brain, the link between cognitive appraisal and stress is potentially understandable as an interaction of the mind and body.

Psychologists have identified several factors that seem to influence how stressful a situation seems. One classic study looked at everyday sources of stress in urban environments; one factor identified as influencing the impact of stressors is *predictability* (Glass and Singer 1972). For example, people who live near subways or railroad tracks often show no discomfort from the sounds, which tend to occur at fixed times. Visitors, however, may be greatly stressed by what they see as 'unpredictable' noise. A second factor that affects our appraisal of a situation is *perceived control*. That is, having control of the situation (or even *feeling* that you have control even if you don't) can reduce the effects of a stressor. For example, a field experiment done in a nursing home showed that when individuals were given more choices in their daily routine, they experienced less stress (Langer and Rodin 1976). By contrast, a range of studies have shown that when people develop the sense that they have no control of a situation (a phenomenon sometimes called *learned helplessness*), they experience increased stress and depression (Peterson *et al*. 1993; Maier and Watkins 1998). Thus, the way we perceive the situation may be an important factor in reducing our susceptibility to stress.

The third key factor, along with the situation and our perception of it, is the way we try to cope with the situation. Hans Selye distinguished two types of reactions to a stressor: those responses intended to *resist* the situation (*catatoxic* reactions) and those intended to help one *adapt* to the situation (*syntoxic* reactions). If someone cuts in front of you on the motorway, you may get angry and upset (an aggressive, catatoxic response), or you can laugh and dismiss the other driver's behaviour as foolish (an adaptive, syntoxic response). While Selye suggested that a syntoxic response is often preferable, unfortunately he offered very little direct evidence to support this view.

More recently, researchers have studied differences between problem-focused strategies and emotion-focused strategies (Lazarus and Folkman 1982). Problem-focused coping attempts to deal directly with the situation, viewing it as a problem to be solved. By contrast, emotion-focused coping concentrates on the individual's internal emotional state, and leads to avoiding the problem, blaming oneself, or engaging in fantasy or wishful thinking as responses to the stressful situation. Unlike Selye's model, Lazarus and Folkman did not suggest that one strategy is always preferable. Instead, they suggested that problem-focused strategies are more likely to be used when the situation is perceived as being controllable – for example, in dealing with work-related stressful situations. By contrast, they argued that emotion-focused coping is likely to occur in dealing with situations that are perceived as not controllable – for example, health problems, or a natural disaster (such as one's home being destroyed by a storm). Research suggests that matching of strategy and perceived control does tend to occur, but interestingly, the results do not demonstrate that changing coping strategies necessarily leads to less stress (Zakowski *et al*. 2001).

Clearly, a number of factors influence stress, both within the individual and within the situation (see also Figure 2,12, discussing the role of culture). While it would be appealing to end this discussion with a precise statement about how to cope with stress, at present, defining an 'optimal' response is not possible. This may reflect the difficulty in defining a stressor, or maybe we need to rethink the nature of stress itself. One researcher, endocrinologist Bruce McEwen, has argued for the concept of 'allostasis', which considers stress within the context of the energy demands of behaviour (McEwen 2002). McEwen has argued that this concept can explain the relationship between 'normal' behaviour (such as foraging, breeding or migrating) and stressful situations; for example, foraging is not normally stressful, but would cause stress when food is scarce. In addition, he has suggested that allostasis can also shed light on factors such as gender differences in stress. The latter point has also been supported by psychologist Shelley Taylor and her colleagues, who suggest that women are more likely than men to engage in nurturing and socializing as ways of coping with stressors (Taylor *et al*. 2000). Given the variations in the way individuals respond, the most reasonable advice that can be given in terms of coping with stress is that we should:

Figure 2.12 Stress and Culture

Stress and Culture

Stress, like beauty, often seems to be in the eye of the beholder. As discussed in this chapter, many of the factors that influence our perception of stress are individual. Yet there are also indications that a person's culture plays a significant role in determining what is a stressor. For example, psychologists, sociologists and anthropologists have noted that cultures can often be loosely divided in terms of the culture's value of individualism vs. collectivism. An individualistic culture, such as the USA, emphasizes the rights of the individual above those of the group—a value which promotes the development of independence in its members. A collectivist culture, such as many parts of Asia, values the group (usually the family) and its welfare above the concerns of the private individual. In so doing, the individual is encourages to develop and maintain strong group ties and responsibilities. Bond (1991) found that people who live in collectivist cultures, such as India, Thailand and China, showed fewer stress-related illnesses than people living in individualistic cultures such as Canada and the USA. It is thought that one reason for this is that in collectivist cultures, there is always a support group for the individual, to help with everything from finding a job and maintaining financial security, to choosing a mate and raising children. (Note that social support is a factor which can reduce stress in any culture, but some cultures place greater emphasis on maintaining support networks.)

There are also cultural variations in the kind of strategies which individuals use to cope with stress. In some cultures, 'escape values' in the form of emotional outbursts are seen as acceptable. In India, emotional outbursts in family arguments that to an outside observer may seem to be extremely hurtful, in fact typically leave no permanent mark on the family relationships (Laungani 2001). In other cultures, such as some in Africa and Malaysia, 'demonic possession' is used to give people a societally acceptable way of letting out their accumulated frustrations and stresses (Lee and Ackerman 1980). While clearly there are differences in how people in different cultures tend to deal with stress, there is little evidence comparing the effectiveness of these strategies. Emotion-focused strategies may serve the function of reducing autonomic nervous system arousal, thereby helping to reduce stress—but why particular cultures favour different strategies is still an unsolved mystery.

1 acknowledge how our perceptions influence our reactions;
2 recognize when we are stressed; and
3 develop a range of possible coping responses.

Perhaps the best illustration of successful adaptation was offered by Selye's own behaviour. At the time of writing his last book, he would normally get up at dawn to bicycle five miles to his office, and then work until 8p.m. – and this from a 68-year-old man with two artificial hips!

FOR FURTHER CONSIDERATION

What are the primary stressors in your life? Do they relate to school? Work? Personal life? Given the preceding discussion, can you envision steps you could take to reduce your level of stress?

Mental States and Health

One of the clear implications of research on stress is that our behaviour can affect our health. Since stressors are partly defined by our perceptions, and stress reactions affect the immune system, this points to a link between mental states and physical health. To many people, this is a surprising idea. After all, we have grown up accepting a model of health in which disease processes are due to pathological agents – either invading germs, or defective cell processes. Surely such events have nothing to do with laughter or loneliness!

In fact, research today seems to be pointing to a very different conception of health and healing. Consider some of the clues offered in the research considered already: While neural and hormonal pathways appear distinct, the two systems are also highly interrelated. Processes like chronic stress affect both systems – and also affect the immune system. Meditation in some ways appears to be the opposite of stress, with beneficial effects on body processes. While such observations suggest a relationship between mental states and health, they don't adequately explain how mental states could affect the course of disease.

The possibility of mental states affecting health has a long, if unconventional, history. Every doctor can tell stories about patients who have recovered despite an unfavourable prognosis, or conversely, of patients who should have survived, but died. Traditionally, if they spoke of such cases at all, doctors referred to 'the will to live' or used similar phrases. One such case has become well-known. In the 1970s', Norman Cousins, the long-time editor of *Saturday Review* magazine in the United States, was diagnosed with Hodgkin's disease, a form of cancer which attacks the immune system. His doctors were pessimistic about the outcome, but Cousins decided that giving up would only hasten his end. So, while treatment (chemotherapy, etc.) was in progress, he embarked on a determined programme to bolster his spirits; perhaps the best-known aspect of his plan involved viewing classic comedy films in his hospital room. In the end, Cousins recovered. Although he was grateful to his doctors for their treatment, he also was convinced that, in the old phrase, laughter is truly the best medicine. As a result, he embarked on a quest both to document this belief, and to understand the processes involved (Cousins 1989).

At the time of his recovery, Cousins's ideas were widely dismissed as delusional or at best, a type of placebo effect. (**Placebo effect** refers to the phenomenon whereby labelling an inert substance as a drug – e.g., a 'painkiller' – produces effects similar to the real drug. Of course, how this occurs is in itself something of a medical puzzle!) Then, as discoveries were made about the functioning of the immune system, new theories and data began to emerge. Today, the study of mental states and their effect on health is referred to as **psychoimmunology** (or sometimes psychoneuroimmunology) (Cohen and Herbert 1996). Just as research led to recognition of the interrelations between the nervous system and the endocrine system, there is also a new awareness of how *both* of these are related to the functioning of the immune system.

placebo effect a phenomenon whereby inert substances labelled as drugs (such as a painkiller) produce effects similar to the real drug.

psychoimmunology the study of mental states and their effect on health, as expressed through the functions of the immune system; sometimes referred to as psychoneuroimmunology.

Psychoimmunology is a fast-developing field, and it is impossible to summarize all of the current research, but a few examples can help to clarify the direction in which the field is moving (for general reviews, see Ader 2000; Sternberg and Gold 1997). As noted in discussing stress, it has long been known that high stress levels increase the likelihood of disease. The more recent research suggests that a wide range of social-environmental factors may affect health either negatively or positively. Generally, negative interpersonal events, such as the death of a loved one, or marital conflict, have been identified as having a negative affect on health (O'Leary *et al.* 1997; Maier and Laudenslager 1985; Solomon 1990). On the positive side, patients recovering from heart attacks do significantly better if they have a good social support network, or even just have a pet for company (Cousins, 1989; Oxman *et al.* 1995). There are also some indications that laughter may be beneficial to health (R. A. Martin 2002). One concern with the available evidence is that most studies are *quasi-experiments*, since researchers cannot control the life events, but the results suggest that something is happening in terms of a pattern. The question is, how do such psychological and social influences get translated into immune responses?

While Hans Selye correctly noted that chronic stress resulted in a deterioration of the immune system in experimental animals, he did not know the precise mechanism. Today, advances in biochemical techniques are helping to provide answers. In general, the linkage seems to be based on the impact of hormones on the immune system. One of the earliest clues involved the role of neuropeptides – particularly the 'natural opiates' called *endorphins*. As noted earlier, neuropeptides play a role in both the nervous system and as hormones. Endorphins serve as natural painkillers in the brain, and receptors for them have been identified at a number of sites, particularly in the brain tem. Interestingly, studies have also shown that a number of types of immune cells, collectively called *monocytes*, also have receptors for endorphins – and that the endorphins play a role in regulating the activity of the immune cells (Maier and Laudenslager 1985; Pert 1990). At a higher level, there is evidence for interactions between the hypothalamic/pituitary/adrenal (HPA) system of the fight-or-flight response and the immune system (McEwen and Wingfield 2003; Michelson *et al*. 1995; Sternberg and Gold 1997). While the linkages between the two systems are complex and not yet fully understood, it appears that cortisol and other steroids play a key role in both. As noted in discussing stress, steroids play an important role in regulating metabolic functions as part of the fight-or-flight response, and also regulate immune function. As a result, situations which promote a chronic stress response also produce inhibition of the immune system. This connection has been supported by research that shows that couples experiencing marital problems show both elevated cortisol levels and poorer health (Kiecolt-Glaser *et al*. 2003; Keicolt-Glaser and Newman 2001). In addition, there is evidence that the type of coping strategy individuals use to deal with stress affects both cortisol levels and immune system functions (Bosch *et al*. 2001; Stowell *et al*. 2001).

While many details remain to be clarified, the notion of mental states affecting health can no longer be considered a delusion or fantasy. At the same time, one must be cautious about drawing conclusions based on the available research. While mental states may play a role in health, none of the researchers involved is suggesting abandoning conventional medical treatment. If anything, the implication seems to be that doctor–patient relationships are more important than ever to effective health care. Thus, the traditional 'good bedside manner', downplayed in the rush of new medical technology, becomes once more an important adjunct to medical treatment. At the same time, an important concern has been raised by Marcia Angell, editor of the *New England Journal of Medicine.* Essentially, Angell argues that telling patients (particularly those with terminal illnesses) that their attitudes and behaviour produced their condition can add an unjustified burden of guilt on those already afflicted – especially in the absence of direct evidence (Angell 1985). Cancer, for example, may arise despite 'positive thinking', since other factors are clearly involved (including genetic factors and environmental hazards). Regardless of what future research on psychoimmunology reveals, the multi-faceted nature of health is unlikely to change. What may change, however, is the concept that individuals must be passive in the face of illness.

From the point of view of psychology, the research on psychoimmunology adds a further dimension to our understanding of the relationship between mind and body. In some ways, it brings us full circle back to where we began this chapter. We have seen how processes in the body affect our mental state, and in turn how mental processes can affect the body. Obviously, many questions remain, but the basic assumption of the materialists – that 'mind' and 'body' are different ways of talking about the same thing – seems relatively secure. While we may never be able to do away with one or the other term, research on mind/body issues has led to exciting discoveries about how we function. In the end, it is these advances in our understanding that justify the biological approach.

FOR FURTHER CONSIDERATION

An old saying suggests that 'laughter is the best medicine'. Given current knowledge of psychoimmunology, would you agree or not? Do you see any practical way to apply this idea?

THE HEREDITARY BASIS OF BEHAVIOUR

While the relationships between mind and body are significant, there is one element of our biological nature that has not been discussed. The human brain is an incredibly complex structure, unparalleled (so far as we know) in the universe. The body, too, with its highly integrated systems, is a wondrous thing. But how did our complex physical structure arise? How do nerve cells grow and develop into the specialized networks that make up the brain? What determines the variability found between individuals – not just in height or eye colour, but also in the brain? (Edelman 1992). To try to answer such questions, we must look at another aspect of the biological approach – the study of *heredity*.

In the 1970s, a group of researchers announced that they had found a genetic pattern associated with criminal behaviour. They had discovered that certain men were born with an extra Y chromosome; individuals with the resulting XYY pattern, the researchers argued, tended to become criminals. This assertion led to great controversy, both among researchers and the general public. If someone could be identified at birth as a potential criminal, advocates argued, they could be closely watched, or even locked up before they could cause harm. Opponents questioned both the evidence, and the moral principle of prejudging guilt. Soon, other researchers discovered that many XYY men existed who had no apparent history of criminal actions. Given this and other contrary evidence, the XYY-criminality theory was cast into doubt, and the controversy died (Gould 1981) However, it is significant that, throughout the debate, *no one ever questioned the underlying assumption that behaviour could be inherited*!

The concept of inherited traits has become so widely known and accepted that it is difficult for us to recognize its impact on our thinking. Yet it is little more than a hundred years since Charles Darwin suggested that variations could be passed on from one generation to another. 'Like father, like son', people say – but how *much* like, and *how*? Even Darwin, who believed in the phenomenon of inheritance, had no idea how heredity actually functioned.

evolution a theory to account for the development of species diversity by means of variations which are transmitted to offspring by inheritance; Darwin's theory of **natural selection** proposed that variations which enhance adaptability, and thereby enhance survival and reproduction rates, are the most likely to be transmitted.

Darwin's ideas about inheritance between generations were closely linked to another concept: **evolution**. He recognized that variations existed within a species, and believed that such traits could be transmitted from parents to offspring. Traits which enhanced survival and reproduction rates were the most likely to be transmitted; thus, Darwin's principle of **natural selection** as the basis of evolution is sometimes referred to as 'survival of the fittest'. Darwin believed that the same process which produces variations within a species *also* produces the variations which are ultimately labelled as different species. Thus, all species are ultimately related through the mechanism of evolution. This concept of continuity between species was contentious in Darwin's day (and sometimes still is), but it has significantly influenced the way we view behaviour. For example, one can compare human behaviour and physiology to that of other species as a tool for improving our understanding (chimpanzees, for example, are genetically very similar to humans). This is not to say that chimpanzee studies, or those involving other species, are a substitute for research on humans. Rather, comparisons of similarities and differences can lead us to new questions, and new insights. In a similar vein, paleoanthropologists and evolutionary psychologists study the ancestors of humanity to provide new insights into our own behaviour. Ultimately, the goal of such studies is not to diminish the wonder of human existence, but better to understand and appreciate who and what we are.

These concepts – heredity and evolution – have been significant in improving our knowledge of human behaviour. As we shall see, the pace of research in genetics in particular has been accelerating tremendously in the past few years, so no account can be fully current. However, an understanding of the foundations and assumptions underlying current research can help us better to understand the significance of what George Beadle, a Nobel laureate in genetics, has called 'the language of life' (Beadle and Beadle 1966).

Basic Mechanisms of Heredity

The word 'genetics' was coined by the English biologist William Bateson. In an article published in 1902, he urged his fellow researchers to look at the causes of inherited resemblances and differences, to understand 'the essential process by which the likeness of the parent is transmitted to the offspring'. At first, Bateson drew little response. For many years, the study of genetics was considered a bit eccentric, being based on taking inventories, raising generations of fruit flies, keeping animal pedigrees, and talking about concepts like 'dominance', 'unit characters' and 'ratios'. At the same time, chemists were working on the chemical structures of enzymes and other organic chemicals. Although it took many years before they realized it, both groups were working on the same problem. Ultimately, the result was the breaking of 'the code of life', embodied in the chemical structure of genes.

What is perhaps most fascinating about the development of genetics is that the early population geneticists (like Bateson) came to a clear understanding of the basic properties of genetic inheritance *without* any knowledge of the underlying biochemistry. In fact, the basic mechanism was identified by an Austrian monk named Gregor Mendel more than 100 years before anyone actually isolated a gene! The son of a farmer, Mendel became interested in problems of plant hybridization (the crossing of different strains to produce new varieties). Working with garden peas, he set up an experimental plot to see if he could determine some orderly principles underlying the results of hybridization. As it turns out, he was wrong on many details, but correct in the general outline. Mendel discovered that an inherited characteristic passed from parent to offspring. (Mendel, of course, did not know that it was a *chemical* process, but he knew there must be a mechanism.) In any individual, this code is made up of two genes, forming a pair. When reproduction takes place, the gene pair is split, so that one parent contributes only one gene to the offspring; the other member of the offspring's gene pair comes from the other parent. Thus, the offspring carries genetic information from both parents.

gene the basic unit of heredity, made up of sequences of 'building blocks' called amino acids; it is estimated that humans possess about 30,000 different genes, each regulating production of various proteins.

chromosomes thread-like genetic structures composed of double strands of DNA and proteins, containing the genes; in humans, there are twenty-three pairs of chromosomes.

Today, thanks to the advances made in biochemistry, research in genetics has moved from hypothetical concepts to molecular processes. We now recognize the **gene** as the basic unit of heredity, made up of sequences of building blocks called amino acids. The genes in turn are part of the larger structures called **chromosomes**. Understanding this complex structure has been one of the most remarkable achievements in modern science. Consider this chronology: in 1953, fifty years after Bateson coined the term genetics, the basic structure of chromosomes was deciphered by James Watson and Francis Crick. However, it took almost another twenty years before anyone actually isolated a single gene. As recently as

Figure 2.12x Cells, Chromosomes, Genes and DNA – Every cell (left) contains a nucleus, which contains a set of chromosomes (middle); the chromosomes in turn are made up of strands of DNA (right). Genes are composed of segments of the chromosomal DNA.

— A/W to come —

1990, less than 1 per cent of the total 'string' of 3 billion amino acids in human DNA had been identified. Subsequently, thanks to an international research effort called the Human Genome Project, a basic 'map' was completed in 2003, almost exactly 50 years after Watson and Crick's discovery (Collins *et al*. 2003; Lee, 1991). Because of the techniques used (essentially, cutting up the genetic material, analysing it, and then trying to reassemble it), there are still gaps and limitations. One critical limitation is that no one yet knows precisely how many active genes humans have; most researchers believe there are about 30,000 genes, but some estimates go as high as 66,000. To give some comparison, as of 2003, about 1500 disease-related genes had been identified, along with a variety of other genes. Leaving the numbers aside, what does this have to tell us about the origins of behaviour? How does inheritance work, and what is it that is inherited?

As Mendel had hypothesized, genes are the fundamental units of inheritance. However, it turns out that the mechanism of splitting and recombining (which provides for variability) across generations depends on the chromosomes. Composed of double strands of DNA and proteins, chromosomes are the large-scale structures of heredity, containing the genes. In humans, there are twenty-three pairs of chromosomes, each holding thousands of genes, like pearls on a necklace. Because each of the twenty-three pairs of chromosomes splits and recombines independently of the others during reproduction, there are 2^{23} possible chromosome combinations from each parent, meaning that genetic recombination provides for almost limitless variety. (With over 8.4 million combinations from a single set of parents, the likelihood of even two siblings having identical sets of chromosomes is very small.) The result is that genetic mechanisms provide a basis for variability, as well as similarity, from parent to offspring.

genotype the genetic code which an individual carries in the DNA of their cells.

The genetic code which an individual carries in the DNA of their cells is called their **genotype**. Genes function in pairs, and the gene-pair members for particular characteristics (for example, blood type, eye colour) come in several variants, called *alleles*. Each allele repre-

unigenic inheritance genetic transmission which is dependent on the action of a single pair of genes; also called Mendelian inheritance, in recognition of Gregor Mendel's pioneering work.

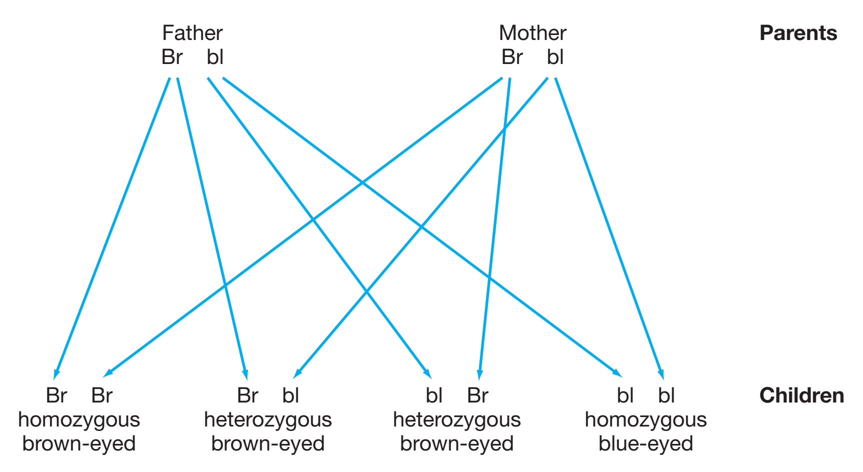
phenotype the observed characteristics of the individual, based on the combination of genotype and environmental influences.

sents the chemical code for a single variation. For example, basic blood types in people are based on three alleles, representing A, B and O. Normally, for a characteristic based on a single gene (i.e., one pair – called **unigenic** or Mendelian **inheritance**), one allele, called the *dominant* allele, will be expressed (that is, active) whenever it occurs in the gene pair. Other alleles will only be expressed (active, and therefore observable in the individual) if both members of the gene pair are the same. Because they are not as influential as the dominant form, these genes are called *recessive* alleles. For eye colour, brown is the dominant form, while blue is recessive (see Figure 2.13). Thus, the observed form of the characteristic depends upon what pairing of dominant and/or recessive alleles of the gene is present. (Note: this description is based on the classical model of unigenic inheritance; while it works very well for the vast majority of cases, research in recent years has indicated ways in which it oversimplifies, and hence occasionally leads to faulty predictions. For the purpose of understanding the basics of heredity, these subtleties are not critical.)

One must distinguish between the genotype, defined by the genes, and the *observed* characteristics of the individual, called the **phenotype**. One reason for this distinction has already been noted: a person may possess a recessive gene for blue eyes, but it will not be expressed if they also have a dominant gene for brown eyes. In terms of appearance, they would seem no different from a person with two brown genes. (Hence, one cannot always determine the genotype simply by observing the phenotypic appearance.)

More importantly, genes only determine a *potential* for a characteristic, which must then be realized through a long sequence of biochemical processes (basically, genes code for the production of proteins, which may in turn affect many basic physiological processes). Along the way, other factors, including environmental influences, may intervene. For example, an individual may be born with PKU (phenylketonuria), a metabolic disorder based on a recessive gene (which differs from the dominant in lacking one amino acid, phenylalanine). If untreated, PKU can result in severe mental retardation. However, appropriate medical treatment and dietary restrictions can compensate if the disorder is detected early, and the individual need never suffer the effects. Depending on the particular characteristic, the amount of environmental influence differs. The genetic code for most aspects of our physical structure is relatively rigid – for instance, dictating the location of the eyes. For traits related to behaviour, such as intelligence, the reverse may be true – environment may play a decisive role. Consequently, one cannot easily generalize about the genetic expression, except to note

Figure 2.13 **Unigenic Inheritance** – As discussed in the text, observed characteristics like eye colour depend on the individual's genetic make.up, inherited from the parents. If both parents are heterozygous brown.eyed, then the unigenic model says they have a 25 per cent chance of any child being homozygous blue.eyed, as the combinations suggest.



that the observed characteristics of an individual (the phenotype) are based on a combination of genotype and environmental influences. Because of this, even genetically identical individuals can differ; this was vividly illustrated by a cloned kitten which differed in colouring from its genetically identical 'mother' (Taeyoung *et al*. 2002). For psychologists, the nature of genetic expression is one of the most important aspects of heredity.

To summarize thus far, inheritance of characteristics is based on a chemical code carried by genes, which are themselves carried by the chromosomes. Genes function in pairs, and various forms (alleles) of the gene for a characteristic exist. The recombination of genes from parents to offspring provides a basis for genetic variability within families. Ultimately, though, the observed characteristics of an individual depend on the interaction of genetic and environmental factors. As we will discuss, determining the relative role of these factors in behaviour has been one of the major concerns of psychologists studying heredity.

One other issue needs to be considered in relation to genetic mechanisms: the origin of new traits. Although recombination provides for considerable variation, it does not provide for the creation of any *new* traits. Thus, if heredity functioned only in the way described above, there would be no possibility of evolution. Darwin recognized this, even without knowing anything about the basis of hereditary mechanisms. Hence, along with the normal sequence of biochemical processes, it is possible for new gene forms, called **mutations**, to occur. Mutations are very rare, happening perhaps once in a million times. However, when they do occur, by whatever random process, a new trait may appear. Again, Darwin was alert to the significance of such events, which he expressed in the law of *natural selection*: any new trait which offers an advantage in terms of survival will tend to be passed on (because the individual is more likely to survive to reproduce). Conversely, any trait which weakens the ability to survive will normally disappear (if the individual dies before reproducing). Today, this is often referred to as 'survival of the fittest'.

mutation a change in the genetic material of a cell; while rare, mutations can result in new characteristics which may be transmitted to descendants of the original cell.

More recently, a second mechanism for genetic variation has been identified: transfer of genes between different species. (Amàbile-Cuevas and Chicurel 1993). Whether by mutation or other mechanism, the emergence of new traits due to genetic variation is the basis of *evolution*, the development of species diversity. From a psychological point of view, this is significant, because it indicates that the development of human characteristics has a long history. The structure of our brain is linked to the structure of the brains of other species. In the same way, hands are related to flippers and wings. Darwin recognized these connections, but also knew that his contemporaries would not be likely to accept it. So, in his first book, *The Origin of Species*, he carefully avoided any mention of *human* evolution (Darwin 1859). Only in his later writings did he become more explicit.

Heredity, then, is an important key to understanding behaviour. To the extent that it provides the organizational code for the developing embryo, it underlies all that we have talked about in terms of physiological processes. Through evolution, humans have developed the characteristics and abilities that distinguish us from other species. The cortex of our brains, which in many respects seems more highly developed than in other species, has played an important part in those gains. At the same time, the environment, through the effects of experience, has a significant impact on both our biochemistry and our brain. What we are depends on both our genotype and our environment. For psychologists, the major challenge is to understand precisely how these two factors interact.

FOR FURTHER CONSIDERATION

Our increasing understanding of genetics brings with it new dilemmas. For example, it is now possible to determine when an individual has the genes for a serious disorder, such as *Huntington's disease* a fatal neurological disorder, which is due to a dominant gene, but is not expressed until the person is in their 40s). If you had the gene for Huntington's disease, would you want to know? Why or why not?

Nature and Nurture in Behaviour

Of all the disputes in psychology, perhaps the most contentious concerns the relative importance of heredity and experience. Long before Mendel formed his genetic theory, people had an intuitive belief that something like heredity existed. Plato, for example, talked about knowledge being inborn or 'native' to the person, rather than being acquired through experience. This led to the view of knowledge and behaviour called **nativism**, the belief that characteristics are innate (Weimer 1973).

nativism the philosphical view, held by Plato and others, that knowledge and behaviour are innate in origin.

empiricism the philosophical position, first attributed to John Locke, that all knowledge is based on experience; hence, the basis of the view that behaviour is learned.

However, not everyone has taken this viewpoint. Other thinkers have maintained that all new-born babies are basically alike, and only develop unique characteristics as a result of differing experiences. John Locke, an English philosopher, expressed this view in 1690, saying the mind at birth is like a blank paper, on which experience is gradually written (Locke 1690). This view, which emphasizes the importance of environmental influences, is often called **empiricism**.

The philosophical split between nativism and empiricism has led to arguments about the relative importance of heredity (nature) and environmental factors (nurture) in various aspects of human functioning. Advances in our knowledge of genetics have made it possible to identify specific genes related to a variety of disorders, such as Huntington's disease and Tay-Sachs disease (both are fatal disorders which affect the nervous system). With behaviour, the situation is more complex, in part because there may not be a simple equivalence between genes and behaviour. That is, genes typically produce a variety of proteins, which may affect the body in diverse ways; similarly, most behavioural traits are probably influenced by a variety of genes, rather than a single gene as in the diseases mentioned above. Intelligence, for example, is a characteristic for which the relative contributions of nature and nurture are still being assessed. Similarly, the role of heredity in mental disorders like schizophrenia is still not well understood. With such complex aspects of behaviour, the techniques involved in molecular genetics may be of limited help for some time to come. Consequently, the study of genetic influences on behaviour typically involves methods associated with traditional population genetics – tracing observed traits among related individuals.

concordance a technique for studying inheritance by examining characteristics of individuals whose genetic relationship is known.

Ideally, one would like to have total control of both genetic and environmental factors, so that they could be studied experimentally. Although this is impossible both technically and ethically, one can often approximate the ideal by doing **concordance** (literally, 'agreement') studies to examine the characteristics of individuals whose genetic relationship is known. In these studies, *identical twins* are the preferred subjects, because they come from the same fertilized egg, and therefore have the same genetic make-up. (*Fraternal twins*, by contrast, are conceived at the same time, but developing from separately fertilized eggs, they are genetically no more alike than any two siblings.) At a basic level, the logic of concordance studies is easy to understand: Because of the similar genetic make-up of identical twins, if a particular trait is controlled by the *genes*, then the twins should develop similarly, whether they are raised together or in different settings. On the other hand, if *environment* plays the major role in a trait, then the degree of similarity between identical twins should depend on how they were raised – if raised together in the same family, they should show some similarities, as do any siblings. However, if raised *apart* from each other (for example, in separate adoptive families), identical twins should be more like members of their adoptive families than each other. Concordance studies can also involve other genetic relationships, such as fraternal twins or other siblings, or parent–child comparisons. In each case, the goal is to measure behavioural similarities in accordance with what would be expected based on the degree of genetic similarity. (For example, on average, any child shares 50 per cent of their genes with each parent, as do siblings; a grandparent and grandchild share 25 per cent of their genes on average.)

Unfortunately, although the concept of concordance is fairly straightforward, the methodology is not as clear-cut as it may seem. Although identical twins are the preferred group, such twins are quite rare, and finding cases where they have been separated at an early age (due to parental death, marital break-ups, etc.) are rarer still. In addition, the fact of separation may make it difficult for researchers to locate both twins at a later time. (In some cases of separation in infancy followed by adoption, the children are not informed that they have a twin.) When separated twins *are* located, the degree of separation can be hard to assess. In one case, a researcher described twins as 'separated' who had been separated in name only – for example, one raised by the parents, and one by a maiden aunt who lived one hundred yards away (Shields 1962). Determining early history is a crucial factor to the validity of concordance studies, because when twins actually have contact despite living under different roofs, it cannot be claimed that the environments are truly different. Even when twins are separated at birth and raised separately, they still share the same prenatal environment in the mother's womb (and for this reason, fraternal twins tend to be more alike than other siblings, since they are conceived and born at the same time – but this reflects an *environmental* influence, not heredity). Consequently, it is a practical impossibility to find identical twins who have grown up in completely different environments, and assumptions about twins reared apart may overestimate the contribution of heredity to observed similarities.

At the other end of the scale, is the idea of studying two individuals (regardless of genotype) who have grown up in identical environments. Unfortunately, this is equally tricky. Twins raised in the same family appear, superficially, to meet this criterion because both prenatal and postnatal circumstances are shared. However, even when two children grow up in the same family, there is no guarantee that they will have identical experiences, or be treated in exactly the same way. This becomes especially clear when one considers fraternal twins of different sexes. Regardless of their shared prenatal environment, they are likely to encounter increasingly different circumstances as time goes on, due to social factors (for a discussion of current research results, see Chapter 7).

Apart from the methodological difficulties, concordance studies have sometimes oversimplified the issue (much like early philosophers did) by assuming that behaviour is due to heredity *or* environment. Over time, both psychological and genetic research has led to a growing recognition that the picture is more complex: genetic predispositions can lead people to make changes in their environment, and the environment can trigger genes to turn on or off. As a result, most psychologists today accept an *interactionist* view, which suggests that genetic and environmental influences are interwoven in determining the final shape of behaviour. (Denenberg 2000). In this sense, the answer to the question, 'Is it nature or nurture?' is actually, 'Both.'

FOR FURTHER CONSIDERATION

Suppose that scientists created a clone (genetic duplicate) of you. Would you expect them to be identical to you when grown? What does your response tell you about your own view of the nature/nurture issue?

Evolution and Behaviour

While it can be difficult to determine precisely how much heredity influences behaviour, there is little doubt that it plays a significant role in what we are. However, the mechanism of heredity applies not just to the transmission of characteristics from parents to children, but to the whole process of evolution described by Darwin. What we are as a species (and therefore as individuals) is influenced by our evolutionary history, and our heredity provides clear links to that history. For example, there is an approximately 99 per cent overlap in the genetic material of people and chimpanzees. The 1 per cent difference is obviously significant (for example, in the development of language areas in the cortex), but the implication is that we share a great deal of our nature with other species. This concept, which flows naturally from both Darwin's theory and basic data about genetics, has led to the development of a new sub-area in psychology and biology, called **evolutionary psychology**.

evolutionary psychology the application of evolutionary principles to the understanding of behaviour.

Evolutionary psychology attempts to apply the principles of evolution in order to enhance our understanding of behaviour. In many ways, it traces its origin to the ideas of a Harvard University biologist, E. O. Wilson. Wilson, whose speciality is the study of ants, wrote a book advocating the application of evolutionary principles gleaned from the study of other species to human social behaviour (Wilson 1975). Wilson called this approach sociobiology, and wrote a text by the same name. Wilson's ideas were highly original, and also controversial, and that sense of controversy is still evident today in discussions of evolutionary psychology.

According to its advocates, both the body and the brain evolved in response to the pressures of natural selection; therefore, if a functional capacity exists in humans today, it must be because at some stage it conveyed a survival advantage (Barkow *et al*. 1992; Buss 1995). They then attempt to analyse this sequence in reverse, by identifying a brain structure or behaviour, and then attempt to explain its development in a manner consistent with evolutionary principles. Sometimes, this process can be very useful, as when visual researcher Jerome Lettvin used ecologically relevant stimuli (bugs, stems, etc.) to understand visual processing in the frog's eye (Lettvin *et al*. 1959). Lettvin reasoned that a frog's eye evolved to adapt to its environment, and that therefore such stimuli would probably provide a better understanding of functioning than would arbitrary stimuli like spots of light or simple lines. The resulting study, considered a classic, was both insightful and highly influential. In a similar vein, the idea that parts of the brain evolved at different rates, and in response to differing demands, is proving useful in our attempts to understand brain functions. For example, LeDoux has argued that because the brain structures involved in emotion evolved before the cortex, we should not assume that the cognitive (conscious) aspects of emotional experience provide a full picture of the role of emotions in our survival (LeDoux 1995).

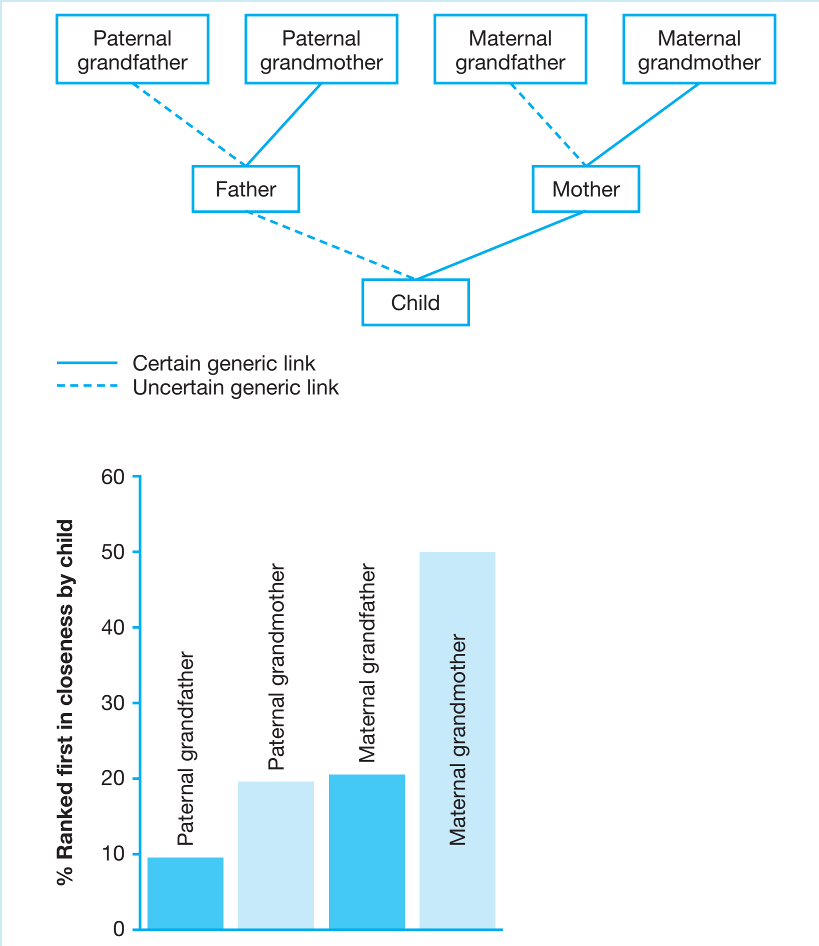
Thus, evolutionary theory provides a useful point of reference as we strive to enhance our understanding of the brain. As Nobel Laureate Gerald Edelman notes, we need to recognize that the nervous system has an evolutionary history which is relevant to its current structure and functioning (Edelman 1992). Yet there remains a significant gap between acknowledging that the brain has evolved, and determining the specific ways in which evolutionary theorizing can explain behaviour. For instance, Wilson has tried to argue that morality has an evolutionary basis, even though he admits that we lack the evidence to prove this assertion (Wilson 1998).

One area that has been hotly debated is the relevance of evolutionary interpretations of gender. It seems obvious that differences exist between men and women – for example, men are typically larger and stronger, and women tend to live longer. Does this mean there is an evolutionary reason for these differences, and therefore that gender differences can be understood by trying to interpret the survival value of these differences? Evolutionary psychologists say yes, and have used this notion to interpret many aspects of gender-related behaviour, particularly with regards to mate selection. For example, it is argued that men are by nature polygamous, because they are capable of impregnating multiple women over a short period of time, thereby increasing the likely survival rate for their genes. (Remember, natural selection says that traits evolve because they carry a survival advantage.) Women, it is argued, are by nature monogamous, because they must invest a great deal, both during pregnancy and after birth, to ensure that their child (and therefore their genes) survive. Whether one finds this reasoning plausible or not, the real question becomes, how can we evaluate it in a scientific way?

One basic problem is that the interpretations (like most ideas in evolutionary psychology) are essentially correlational and *post hoc* (that is, applied after the events they are trying to explain have already occurred). As such, they don't easily allow for the predictive evaluations which most researchers favour. (Recall the discussions about experiments vs. other research methods in Chapter 1.) This is a serious concern, and has led evolutionary psychologists to seek possible experimental tests. One example relates to the concept of *paternity uncertainty*. According to this theory, men are inherently less able to determine if a child carries their genes than women (since in a normal pregnancy the mother always knows that the egg has her genes, but the sperm may or may not be from the claimed father). Hence, evolutionary psychologists have argued that male forebears should be less willing to invest resources in children than are females. For example, a paternal grandfather cannot be certain that his son really is genetically related, and that man in turn cannot be certain his child is really his own. By contrast, a maternal grandmother is completely certain, because she knows her daughter carries her genes, and her daughter knows her own child carries her own genes (and therefore half of the grandmother's as well) (see Figure 2.14).

Drawing on this reasoning, German researchers did a study examining the emotional closeness between grandparents and their grandchildren; as predicted, emotional closeness was consistent with degree of genetic certainty (Euler and Weitzel 1996). This study is interesting not simply for the clear pattern of the results, but also because the outcome is one that most people would find very unexpected. Although technically the research is only a quasi-experiment, it is worth noting that other factors, like where grandparents lived, their age, and availability of other grandparents, did not show any patterns. Thus, it is an example of a study that not only is quite consistent with the evolutionary view, but one where alternative explanations are not obvious. (One factor that cannot be ruled out is the role of culture, since only German families were considered.)

Figure 2.14 Certainty of Genetic Relatedness and Emotional Closeness – Retrospective ratings by adults of which grandparent was emotionally closest to them in childhood reveal a pattern consistent with a model based on certainty of genetic relatedness. (Data from Euler and Weitzel, 1996)



At present, there is no clear consensus about the value of evolutionary psychology. Its advocates appear correct in suggesting that evolution has influenced what we are. The problem, though, is that making retrospective interpretations is fraught with many perils. As with any correlational research, alternative explanations are almost always possible, and observed patterns do not prove a causal link. This difficulty has been noted by Stephen Jay Gould, an American evolutionary theorist who has been a frequent critic of evolutionary psychology. Gould argues that as structures evolve, their function can also evolve – a process he calls *exaptation*. This type of change can then make it difficult to apply natural selection retrospectively as a means of explaining the current function. For example, Gould demonstrated that small wings would have had no advantage for flight, but would be very useful for regulating body temperature; only later, as they became larger, would their potential for flying emerge.(Gould and Vrba 1981). Thus, one could propose that wings evolved in order to permit flying – but one would be wrong! Similarly, we cannot be certain that evolutionary explanations of behaviour are necessarily correct, even when they appear plausible.

The limitations of research in evolutionary psychology are particularly evident when it comes to issues related to gender and sexual behaviour, which are often based on arguments about sexual selection (reproductive success). (Remember that evolutionary theory explains the origin of characteristics in terms of making transfer of the underlying genes more likely.)

For example, sexual selection has been used to explain the adaptive value of pretty faces and symmetrical bodies, and even traits like sympathy and fidelity (Miller 2000). While some of the interpretations may elicit scepticism, consider the more extreme assertion that rape is an evolutionary adaptation in human males (Thornhill and Palmer 2000). Using insect data to extropolate to a behaviour that occurs in only a minority of men seems to place a heavy burden on evolutionary principles. At best, such arguments seem likely to elicit controversy, and at worst, they discredit more serious research (de Waal 2002; Segal,2001).

Controversy, of course, is not always bad, and evolutionary psychology may be of value precisely because it is provocative. As Frans de Waal, a noted primate researcher, has commented, psychology needs to move beyond simple polarities like mind vs. brain, or nature vs. nurture, and evolutionary theories challenge accepted notions about behaviour (de Waal 2002. In that sense, the value of evolutionary psychology may lie in how it reshapes other types of research by suggesting new questions (as in the study of vision or emotion, as noted above), rather than in the specific explanations it provides. In the short run, it seems likely that the debates between its advocates and critics will continue.

CONCLUSION

The biological approach is oriented towards understanding the physiological and genetic basis of our behaviour. Within psychology, it is the only approach which tries to explain behaviour in terms of the workings of the physical system. By contrast, consider psychoanalysis (see Chapter 5): Although Freud was trained in neurology, and believed that ultimately the system was biologically based, psychoanalysis uses concepts which are purely psychological, not physiological. Behaviourism (see Chapter 3) is even more extreme, regarding the body as a 'black box' whose workings are neither known nor relevant to explaining the relationships between stimuli and behaviour. Hence, the biological approach is alone in emphasizing the physical system.

The biological approach, by its nature, focuses on the internal processes associated with physiology and genetics. As important as these processes are in understanding behaviour, they are not the only source of influences. Each individual's behaviour represents a unique combination of genetic factors (heredity) and life experiences (environment). While the biological approach acknowledges the role of environmental factors such as stressors, it does not place primary emphasis on these factors, or the impact they can have on behaviour. Rather, the study of environmental influences is the focus of other approaches, such as behaviourism.

Over two hundred years ago, Julien de La Mettrie made the assumption that the mind has its physical basis in the brain. In the time since, this concept of *materialism* has gained increasing acceptance. Today, as our understanding of physiological processes increases, it seems more and more evident that mind and body *are* fundamentally linked. This is not to suggest that all the questions, such as the nature of consciousness, have been fully answered; in part, mind and brain may represent different levels of description, and the issue may never be completely reconciled. But, our knowledge is increasing, and perhaps most significantly, the insights are being applied – in medicine, in business and in everyday activities. The concept of *stress* has become widely known, as have methods for coping with it. The use of *psychoactive drugs* has radically altered the treatment of mental disorders, with the number of hospitalized patients in the United States being more than halved between 1955 and 1971. Advances in areas like *psychoimmunology* may have even greater impact in the future.

At the same time, problems remain. One of the greatest challenges concerns the complexity of the physiological system. There are approximately 10 *billion* neurons in the cortex of the brain alone, which are interconnected in manifold ways. In addition, there are countless chemical interactions involving *neurotransmitters*, *hormones* and *neuropeptides* – plus environmental influences. This complexity makes achieving a complete understanding of the processes which affect behaviour a daunting goal. Even on a more limited scale, the ways in which factors interact make it difficult to make specific statements about one factor (e.g., stress as a cause of heart attacks) in the absence of knowledge about other factors (e.g., exercise and family history). Similarly, there is a growing awareness that what we are reflects in part our evolutionary history as a species, and this, too, is influencing the kinds of questions asked. All of these factors point to the reality that the picture we have is not yet complete – but that is characteristic of science, and it is likely that missing details will continue to be filled in as research continues.

PUTTING IT ALL TOGETHER – BIOLOGICAL APPROACH

Given the circumstances of his life, and the difficulties he is experiencing, it is evident that Sam is feeling significant stress. When confronted with a heavy workload and the perceived need to be successful, Sam initially experiences the short-term arousal triggered by stressors – what Selye would call the alarm stage of the General Adaptation Syndrome. After this initial reaction, which is mediated by Sam's sympathetic nervous system, his parasympathetic nervous system seeks to moderate his body's reactions, moving arousal back towards equilibrium. However, given the continuing pressures, Sam enters the resistance stage, where many aspects of arousal remain somewhat elevated. This is a deceptive stage, because the individual tends to feel that they are functioning well, not knowing that the body is still at a higher than optimal arousal level that cannot be sustained without significant adverse effects. Some of Sam's procrastinating activities, like playing with his children, may help to reduce his physiological arousal – an emotion-focused strategy. However, because procrastinating doesn't address the actual stressors, this strategy is not completely successful; in this sense, a problem-focused strategy would probably be more effective.

As discussed in the chapter, prolonged stress affects the immune system, and Sam's flu is indicative of this type of effect. Feelings of fatigue can also be a result of the negative metabolic changes stress can produce.

Sam is feeling badly about himself, which may indicate that he is becoming depressed. Stressful life events are often related to the onset of depression. No one is completely sure how this works, but evidence is accumuiating that the hormones involved in a stress reaction (particularly steroids) affect the neurotransmitters serotin and norepinephrine in the brain. The continued activity of these hormones may atrophy neurons in those parts of the brain that contribute to the experience and regulation of emotions (Brown and Barlow 2001).

Consulting a medical specialist might lead to Sam being prescribed an antidepressant and/or anti-anxiety drug, which might help offset some of the biochemical consequences of stress. However, it may be more useful to consider the factors causing Sam's stress. Since many of the underlying circumstances are unlikly to change in the short term, he needs to re-evaluate his situation, and look for more productive ways of dealing with it, as the chapter discusses.

CHAPTER SUMMARY

- The biological approach is based on the assumption of materialism, which asserts that all behaviour has a physiological basis.
- The two primary concerns of the biological approach are the workings of the nervous system, and the role of heredity in behaviour.
- The nervous system is composed of billions of individual nerve cells called neurons; the most significant component of the nervous system is the brain.
- Perhaps the most challenging question in the study of the brain is the understanding of the nature of consciousness, and the relationship between the mind and the brain.
- Various techniques have been used to study the workings of the brain, including case studies, electrical recording (EEG) and stimulation (*ESB*), and computerized imaging techniques (CAT, PET, and MRI scans). Chemical processes have been explored by looking at the role of neurotransmitters, hormones, and neuropeptides.
- The effects of the body on the mind have been studied in various ways, including the study of psychoactive drugs, and the impact of severing the corpus callosum (split brain).
- The influence of mental processes on the body have been examined in terms of the effects of stress; more recently, researchers have begun to look at how mental states affect the immune system (psychoimmunology)
- The study of heredity involves both the direct study of genes and how they function, and also looking at interactions between heredity and environment by the study of twins and other groups who have an identifiable genetic relationship (concordance).
- Evolutionary psychology applies the principles of evolution to gain insight into the way selection pressures have influenced behaviour.

KEY TERMS AND CONCEPTS

materialism
neuron
synapse
nerve impulse
neurotransmitters
central nervous system (CNS)
cortex
limbic system
brainstem
endocrine glands
hormone
neuropeptide
psychoactive drug
electrical stimulation of the brain (ESB)
cerebral dominance
stress
stressor
psychoimmunology
heredity
gene
chromosome
genotype
phenotype
nativism
empiricism
concordance
evolutionary psychology

SUGGESTIONS FOR FURTHER READING

- Colin Blakemore's *Mechanisms of the Mind* provides a very readable and entertaining history of research on the brain. For a more current overview, see Gazzaniga *et al.*'s *Cognitive Neuroscience: The Biology of the Mind*. To gain an appreciation of the complexities which doctors and researchers face, read *The Man Who Mistook His Wife for a Hat*, by Oliver Sacks, a neurologist who is both knowledgeable and wise.
- Two interesting, if idiosyncratic, views of the relations between the brain and behaviour are *The Feeling of What Happens*, by neurologist Antonio Damasio, and *Bright Air, Brilliant Fire*, by Nobel biologist Gerald Edelman. Damasio offers a new interpretation of emotions and cognition, while Edelman discusses how physiology and genetics are converging in their understanding of the nervous system.
- For a fascinating and lavishly-illustrated account of how techniques for viewing the brain have advanced our understanding, read Rita Carter's *Mapping the Mind*.
- *The Stress of Life* is probably the best of Selye's accounts of stress intended for the general reader. For a general review of research on stress, consider Philip Rice's *Stress and Health*.
- For readers interested in the fast-developing area of psychoimmunology, a recent, though technical, overview is provided by Kiecolt-Glaser *et al.*'s Emotions, morbidity, and mortality. Those seeking a simpler account may prefer Norman Cousins's *Head First: The Biology of Hope*, or Bill Moyers's *Healing and the Mind*, which was written to accompany a PBS television series.
- The excitement and challenge of our increasing knowledge of genetics and behaviour is knowledgeably presented in Plomin *et al.*'s *Behavioral Genetics in the Postgenomic Era*.
- Geoffrey Miller's *The Mating Mind* provides a lucid overview of how evolutionary psychology is challenging traditional ideas about human behaviour.

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