2.4 Physiology and behaviour: Localization of function

Learning outcomes

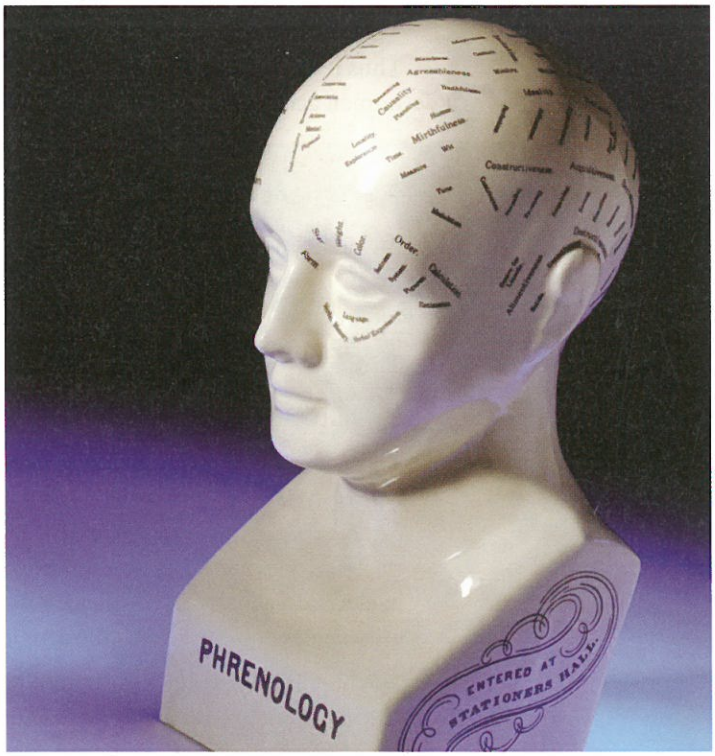
- Explain one study related to localization of function in the brain.
- Examine one interaction between cognition and physiology in terms of behaviour. Evaluate two relevant studies.
- Discuss the use of brain imaging technologies in investigating the relationship between biological factors and behaviour.
- Discuss two effects of the environment on physiological processes.

In this section, we look at the main ways researchers have investigated brain function and evaluate these methods. In your exam, you may be asked to explain a study that uses one of these methods.

Early investigations of localization of function

Early attempts to locate the cause of behaviour in the brain sometimes appear to us now to be rather unusual or even ridiculous. This is partly because of our shared confidence that we understand the brain so much better now because science has developed more accurate ways of investigating the brain. Until more recent times, research suffered from the central problem that it was not possible to directly study the brain in living humans. Thus, it was rather difficult to prove early theories correct or incorrect.

Phrenology is a good early example of brain-related research that now appears inaccurate. Phrenologist Franz Joseph Gall (1758–1828) assumed that certain parts of the brain were responsible for specific facets of personality and behaviour. He believed that by manually searching for bumps and depressions on the skull, one could detect the influence of the brain. Expert phrenologists attempted to make inferences about an individual's personality from this procedure, reaching conclusions regarding, for example, an individual's intelligence and tendency towards murder.



This is a phrenology head. It shows the attempt to map certain functions to certain areas of the brain located by feeling for bumps on the skull.

While phrenology is largely discredited today and many find it ridiculous, it is clear that some of its basic assumptions are still valid. In particular, it is clear that different parts of the brain do indeed have different functions, and that it is possible to study the relationship between brain and behaviour. Research from the 19th and 20th centuries has guided us towards a much better understanding of how we should do such research and how functions of the brain are localized. Localization of function refers to the idea that behaviour, emotions and thoughts originate in the brain in specific locations.

Case studies of people with naturally occurring brain damage

Scientific research into brain function was, until the 20th century, largely limited to case studies of individuals who were known to have suffered some kind of brain damage or head injury. This type of research, not being experimental, could never clearly establish a cause–effect relationship between the behaviour of the person before death and the location of the brain damage. However, it would clearly be unethical to conduct the kind of experiment required, for example, to test what the effect on behaviour might be after a volunteer had a portion of their brain removed.

Probably the most famous example of this type of research is the case study of Phineas Gage (page 44). Gage was a railway worker in the 19th century who survived the passing of an iron rod through his head. He is documented as having undergone dramatic changes in personality after the injury, changes that his doctor blamed on the damage to his brain.

Two further studies from the 19th century revealed important new information about the function of specific areas of the brain. Paul Broca (1824–80) studied a new patient, soon to be known as 'Tan' because this was one of few sounds the patient could make with any frequency. After Tan died, Broca announced that from conducting a post-mortem autopsy on this patient (and several others), he now had evidence that damage to a specific area of the brain was responsible for the loss of the ability to produce coherent speech. This became known as **Broca's area**. The effects of damage to this part of the brain can most easily be observed in the speech of stroke victims, many of whom are temporarily or permanently unable to produce language, a condition known as **Broca's aphasia**.

Another type of aphasia is **Wernicke's aphasia**. This is also a speech disorder, but involving a different part of the brain which seems to be responsible for the comprehension of speech. Individuals with this type of aphasia might have problems understanding the speech of others or might substitute wrong words into planned phrases. Carl Wernicke worked in a similar fashion to Broca, by noting behaviour and conducting post-mortem autopsies to locate brain damage after patients had died.

Thus it was becoming clear that specific parts of the brain were responsible for specific human activities, but it was still very difficult to find ways to investigate this further.

To learn more about Broca's aphasia, go to pearsonhotlinks.com, enter the title or ISBN of this book and select weblinks 2.1a and 2.1b.

Modern technology and localization of function

● Examiner's hint
You need to be able to explain these technologies, what they are used for, and their relative strengths and limitations. You also need to give examples of research that uses these technologies to demonstrate your points.

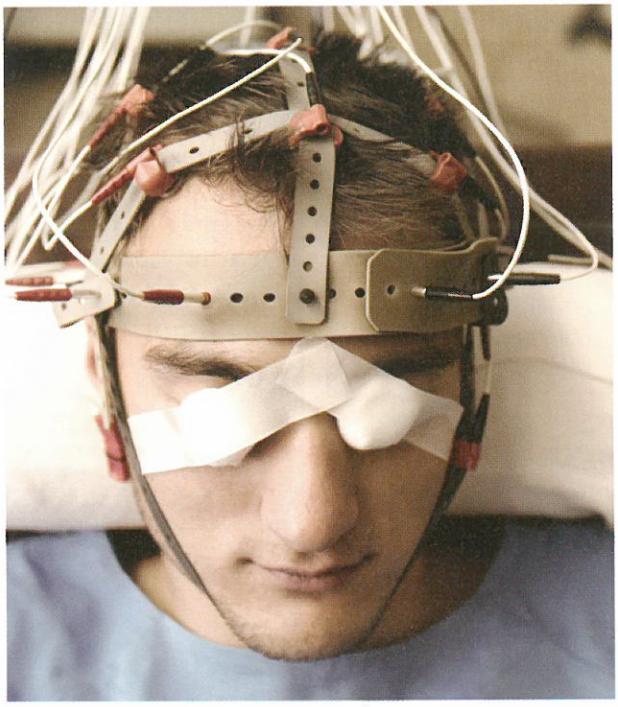
Advances in technology have allowed us to build a more accurate understanding of how the brain works. These technologies include the electroencephalogram (EEG), computer tomography (CT), magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), positron emission tomography (PET).

Electroencephalogram (EEG)

This technology was developed around the beginning of the 20th century and given its name by Hans Berger in 1929. In its present form, electrodes are placed on the outside of a person's head in specific locations. This is often done using a special cap or helmet so that the electrodes are fitted to standardized places on the skull. The electrodes detect changes in electrical activity below them. When areas of the brain are active, the EEG produces a graphical representation of the activity from each electrode.

The best known use of this technology is for sleep research, which requires a person to spend a night 'wired up' to the machine. The researcher or doctor can look at the set of lines printed by the machine and compare them to the graphs usually produced during

sleep. Research has established that brain activity changes in specific ways during sleep. For example, there is a clearly distinct pattern of activity during rapid eye movement (REM) sleep when a person is dreaming. Although it is very useful in this context, the EEG is not sufficiently accurate for most research into localization of function. The reason for this inaccuracy is that the electrodes are outside the skull, and detect the activity of an uncountable number of neurons on the surface on the brain. Thus, we are given a vague idea of what parts of the brain were active, but this is not enough to make strong conclusions in relation to localization of function, so more accurate means of detecting brain activity have been developed



This person is undergoing an EEG in a sleep clinic.

Computed tomography (CT)

The CT scanner combines computer and X-ray technology. A traditional X-ray image shows human bones extremely well, but not soft tissue such as the brain. Computer technology has allowed us to see the brain. The images acquired from a CT scan can be taken from the top, bottom, back, front or sides of the head and can show the brain at any depth. The images look like slices of brain. This technology used to be called computed axial tomography (CAT), where *axial* indicated that it was limited to scans from only one angle.

CT scans are extremely useful for showing structural changes in the brain. For example, structural changes due to a brain tumour or brain damage are very evident on a CAT scan. However, this technology has its limitations. The main one is that a structural image is the only kind of image this technology can produce. Other technologies are needed to provide images of brain activity. The case study of Janet (page 45) provides an example of how this scanning technology is used.

Radiologist examining a CAT scan.

Magnetic resonance imaging (MRI)

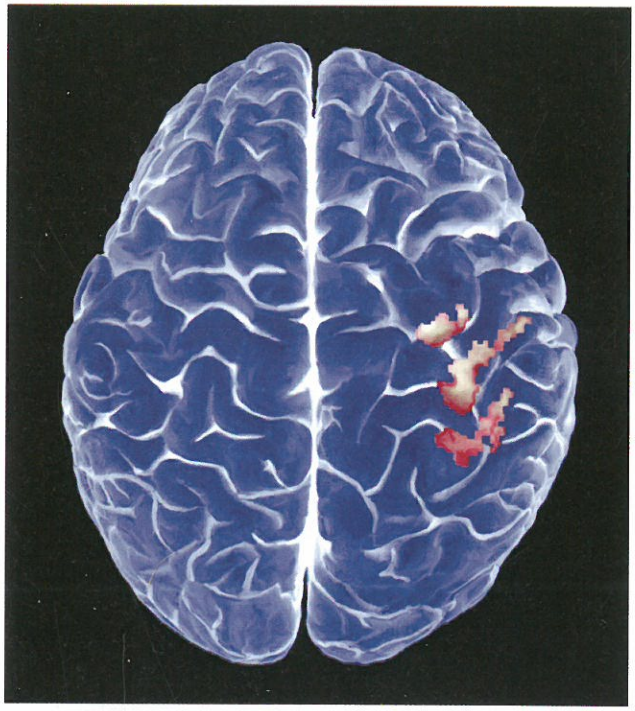
This technology is based on the discovery that when the body is exposed to a strong magnetic field, the protons in the water inside the body change their alignment. When a magnetic field is used in conjunction with radio frequency fields, the alignment of the hydrogen atoms is changed in such a way as to be detectable by a scanner. The signal from the scanner can be transformed into a visual representation of the area of the part of the body being studied. The exposure to magnetism can be dangerous for some individuals, such as those with metal screws used after surgery for broken bones. But for most people, MRI is believed to be safe, and is often preferred over the CT scan for tumours where exposure to X-ray radiation might cause concern. The image that is produced can represent a slice of the brain taken from any angle, and can now also be used to create a three-dimensional image of the brain. MRI technology is still being enhanced, allowing specialists to obtain more precise images of the structure of a brain.

Functional MRI (fMRI)

This is a modification of the regular MRI technique. It takes advantage of the fact that when neurons in a particular region are active, more blood is sent to that region. The fMRI machine can map metabolic changes that indicate brain activity to provide us with a picture that shows with increasing precision which parts of the brain are active while certain activities are being performed or certain thoughts or emotions occur. This clearly allows for a wide range of human behaviours, thoughts and emotions to be correlated with brain activity as they happen, to help us understand the role of certain parts of the brain. It is more flexible than regular MRI in its ability to provide dynamic rather than static information. It is also more precise than positron emission tomography (PET), another method of studying dynamic function.

To learn more about MRI, go to www.pearsonhotlinks.com, enter the title or ISBN of this book and select weblink 2.2.

The study of meditating monks (pages 46–47) is an example of fMRI use in research.



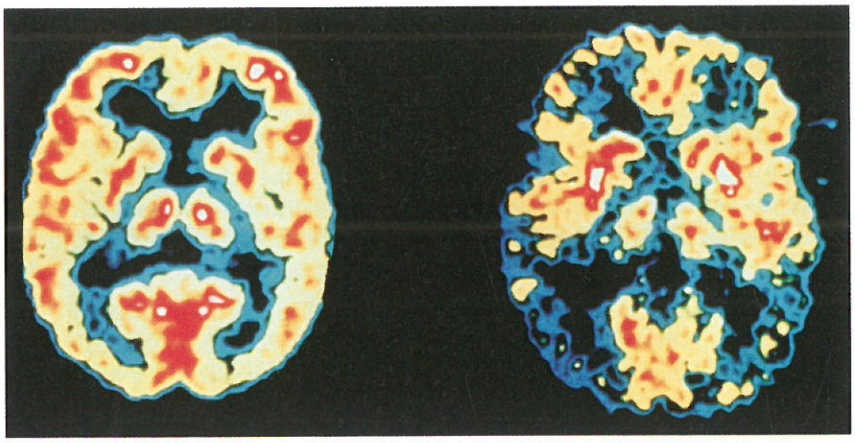
This fMRI scan shows activity in the right hemisphere of the brain.

Cognitive brain-imaging researchers are increasingly able to use technology to show what people's brains are doing. Showing participants static images or video footage and using a computer to find similarities in brain activation has also allowed researchers to do the reverse: look at brain activation in an individual and use it to predict what the person is visually imagining – with increasing accuracy.

Positron emission tomography (PET)

This technology requires the injection of a radioactive substance into the participant. Usually, this is a form of sugar that produces gamma rays as it is metabolized by the brain. Like the fMRI, this technology relies on the knowledge that parts of the brain will metabolize the sugar at different rates according to whether they are more or less active. The gamma rays produced can be detected by the machine in which the person is placed. Eventually the signal is turned into a computer image that displays a colourful map of activity in the different parts of the brain.

PET is good for showing a dynamic image of activity, but it is much less precise than the fMRI. Its use seems most appropriate now for conditions that do not show structural changes early enough to be detected by MRI or CT scans. For example, a patient with Alzheimer's disease will show some quite dramatic differences in brain structure and activity when the disease has progressed and the amount of brain tissue has decreased in certain areas. However, an earlier PET scan can be a helpful diagnostic tool showing abnormalities in activity levels. As with CT scans, a specialist might have some concerns about carrying out a PET scan depending on specific individual health problems.



This PET scan shows a normal brain (left) and the brain of a patient with Alzheimer's disease (right). Brain activity (red and yellow areas) is much reduced in the brain on the right.

Studies of individuals who have undergone brain surgery

HM

One of the most famous personalities in psychology died in December 2008. Known as HM, he was studied regularly for many years after brain surgery in 1953 to correct his epilepsy. An important part of his hippocampus was removed and when he recovered from the surgery, it was noted that he had now had significant memory problems as detailed (page 44). This allowed researchers to make inferences about the role of the hippocampus in memory, although of course there are a number of factors that made it difficult to be sure about cause and effect here. For example, it was not clear until 1997 exactly what the extent of damage to the hippocampus was. Moreover, HM was using anti-epileptic drugs after the operation, some of which are suspected to have caused further damage to his brain.

To learn more about HM and read his obituary, go to www.pearsonhotlinks.com, enter the title or ISBN of this book and select weblink 2.3.

Sperry and the split brain

The work of Roger Sperry (page 45) was very influential in helping neuroscientists to understand the way brain functions appear to be not only localized in specific regions, but also lateralized –that is, the left and right hemispheres seem to be more or less responsible for certain activities. The participants in Sperry's work had all undergone an operation to reduce the severity of their epilepsy by severing the corpus callosum. The corpus callosum is a part of the brain that joins the two hemispheres and it appears to be responsible for communication between them. Without this communication and under the right experimental conditions, the two hemispheres could be studied separately and their sometimes subtle differences identified.

EXERCISES

2 Read the studies in the following Empirical research boxes.

a Which one provides the most reliable information about the functions of the brain?

b Which one is the most useful?

You may like to refer to sections 1.2 and 1.3 (pages 2–8) for guidance.

3 Sperry's work is sometimes considered a natural experiment although others argue it is a case study. What do you think? Can you generalize the findings of this research to the rest of the human population? Explain your answer.

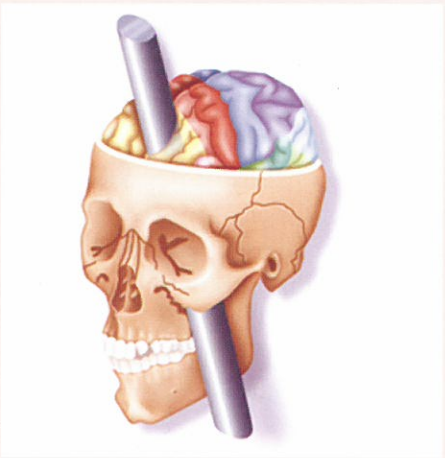
Disinhibition is quite common following head injury. When the brain moves forward inside the skull, the prefrontal cortex is often damaged by the bones around the eye. Disinhibition results in a loss of resistance to carrying out impulses; angry outbursts, for example, are not stopped as they might be in people without this kind of damage.

EMPIRICAL RESEARCH

The case of Phineas Gage

Phineas Gage was a liked and respected foreman for a team of railway workers. In 1848, while he was using a tamping iron to press explosives into a hole, an explosion sent the rod through his head. It entered below his left cheek and exited through the top of his skull. Under the care of his physician, J.M. Harlow, he was nursed to recovery but significant changes in his personality were noted. Harlow described him as having little restraint, using extremely rude language, and making grand plans for the future which would be instantly replaced with others.

It is common for people with frontal lobe brain damage to become disinhibited. This means that they start doing things they might normally have stopped themselves from doing, and it appears that this is what had happened to Gage. Although he wanted to continue working, his impulsive and rude behaviour was not conducive to working with other people and he could not therefore continue. It is suggested that he kept the tamping iron with him even when he went on to work in a circus. After his death, his skull was kept and later discovered by researchers who decided to use modern technology to work out what the likely damage to Gage's brain was.



A reconstruction of the injury to Gage's brain.

Opposite, you can see a reconstruction of Gage's injury based on the work of Damasio, et al. (1994). It shows the likely path of the rod through Gage's brain. From this, we can expect that Gage's frontal lobes were indeed damaged in the left pre-frontal region. This would account for his disinhibited behaviour.

The case of HM

At the age of 27, HM underwent surgery to remove the medial temporal lobes in order to reduce the frequency of his epileptic seizures. This operation was not expected to result in the problems that occurred, partly because at the time (1953) it was not clear what role the temporal lobes might have in memory. HM's operation resulted in the removal of more of his brain than was intended – removal of the hippocampus was a particular concern – and had profound effects on his memory. MRI brain scans were carried out in 1996 and showed the surprising extent of damage: besides damage to the temporal lobes, other parts of the brain had been damaged, and it is supposed that this was caused by a bad reaction to the epileptic medication HM was taking.

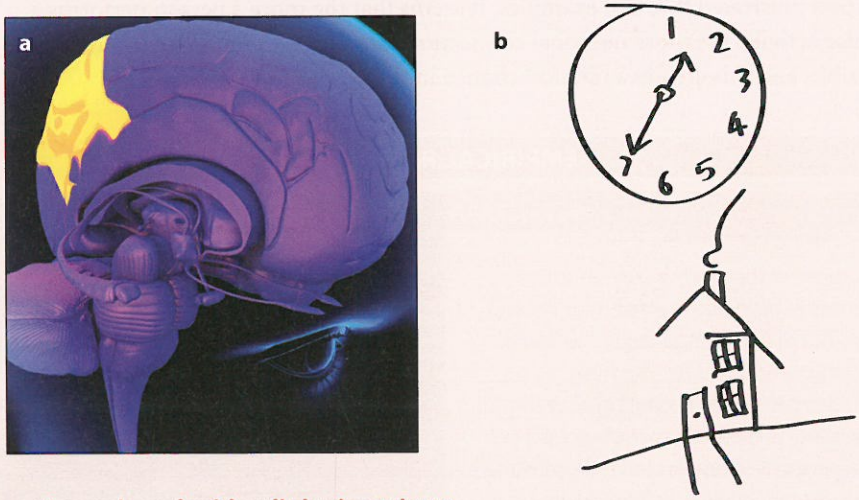
HM's memory problems most famously included an inability to create long-term memories. This means that he could hold information in his working memory, but when distracted, HM would 'forget'. He was able remember some of his childhood, but very little from the 11 years prior to his surgery. This kind of amnesia is known as retrograde amnesia – loss of memory from before an event (surgery in HM's case). Ogden (2005) describes him as unable to detect that time has passed, probably because he is not forming new memories. This form of amnesia is called anterograde amnesia – an inability to remember relating to the time since his operation. It is clear that he picked up a few facts after the operation as he had some idea who Elvis Presley and John F. Kennedy were. His mood is reported by Ogden to be generally calm, perhaps because years of medication have dulled his mood or because of damage to the emotional amygdalae caused by the operation – such damage might prevent the kind of anger that others have felt at being unable to exist beyond a single moment in time. She adds that HM may also be genuinely content and good natured.

The case of Janet

Ogden (2005) describes her study of a woman who died after developing a brain tumour. The case demonstrates the curious phenomenon known as hemineglect. This is a condition that results from damage to one side of the brain and causes various forms of inattention to the opposite side of space.

Janet, for example, was found to have a brain tumour in the parietal lobe of her right hemisphere, detected by CT. Her problems first manifested themselves at a birthday party where she blew out the candles only on the right side of the cake. When reading aloud, she tended to omit words from the left side of the page, and when writing, she would often use only the right side of the page. When asked to fill in the numbers on the face of clock, she wrote on only the right half of the clock, squeezing all the numbers into half the available space. She would also ignore parts of her own body on the left side, even claiming that her left arm belonged to someone else and had been mistakenly left in her bed.

Ogden suggests that this is not from an inability to see or sense, but rather an apparently willing neglect by the half of the brain that is affected. Seemingly errors in performance during neuropsychological assessment can often be accompanied by justifications, rationalizations and jokes that show that patients have some awareness of their own tendencies (although this is more likely when the damage is to the right hemisphere!).



a The yellow area in this image of the brain indicates the parietal lobe. Damage to this area can result in hemineglect. **b** Drawings by a hemineglect patient with damage to right parietal lobe.

Roger Sperry's work with split-brain patients

Prior to his most famous work with human participants (1968), Roger Sperry had already established that when the corpus callosum was severed in cats, it prevented the transfer of information from one side to the other. Myers and Sperry (1953) allowed split-brain cats to learn their way through a maze with one eye blindfolded and found that when the blindfold was removed and put on the other eye, the cats appeared unable to repeat the learned behaviour. They did not detect any other difficulties.

When a group of 10 patients who had undergone a split-brain operation to relieve severe epilepsy became available for research, Sperry and his colleagues began testing the capabilities of each of the two hemispheres to establish what functions might be lateralized in the human brain. Experiments included showing images to only one hemisphere by asking patients to focus on a central point and flashing the image to the far left or right too quickly to allow the eyes to move.

Understanding Sperry's experiments requires the knowledge that *both* eyes send information to the brain about *both* halves of the visual field. Information from the left half of the visual field is sent to the right half of the brain by the optic nerves and information about the right half of the visual field is sent to the left half of the brain. It is necessary to understand that movement of the left half of the body is controlled by the right half of the brain, and of the right half of the body by the left half of the brain. We know from the work of Paul Broca that speech production is a function of the left hemisphere.

continued

To learn more about the work of Sperry and his colleagues, go to www.pearsonhotlinks.com, enter the title or ISBN of this book and select weblink 2.4.

A typical example of the tasks asked of Sperry's participants involved the presentation of a single face consisting of the left half of one person's face and the right half of another's. Participants were asked to describe the face, but their descriptions usually related only to the half-face presented on the right half of space. When shown the full faces and asked to point to the face they had seen with their left hand, participants usually selected the complete version of the half-face that had been presented on the left half of space. Sperry's findings won him the Nobel Prize in medicine in 1981.

The conclusions drawn by Sperry and his colleagues about lateralization of function include the assertion that the right half of the brain is dominant for visuo-spatial ability (demonstrated in tasks like reading maps or recognizing faces), as well as musical abilities and understanding intonation in speech. The left half of the brain seems to be more positive than the right and is dominant for language and logical or mathematical abilities.

● Examiner's hint

Short-answer questions may require you to write an explanation of a study connected with localization of function. Any of the studies in the boxes above are appropriate but note that lateralization of function is not the same as localization of function, so answers using Sperry need to focus on the function of the corpus callosum, not on differences between left and right hemispheres of the brain. In order to write a good answer, you need to describe the study and clearly indicate how it shows that brain functions are localized. For practice, write a one-page explanation of one study, detailing what part of the brain was affected, how the researcher found out, and what the effect on behaviour, cognition or emotion was.

Neuroplasticity

Neuroplasticity is the concept that, although localization of function occurs, the specific location of a function is not necessarily fixed for all individuals, and the area of brain dedicated to certain functions can be redistributed according to environmental demands. This is best illustrated through examples. It seems that the more a person performs a particular activity, the more neuronal connections are formed in the area of the brain responsible, and this creates a physical change in the brain.

EMPIRICAL RESEARCH

The effects of meditation on the brain (Brefczynski-Lewis et al., 2007)

The purpose of this study was to examine differences in brain activity that might have resulted from having engaged in meditation over a long period of time. The main hypotheses were that meditating activates specific parts of the brain that are not active while a person is at rest, and that those with the most experience meditating would show less activity in those regions than less-experienced meditators because experience has reduced the amount of effort required to sustain attention.

Tibetan monk meditating.

The independent variable was experience meditating and the experimenters compared newly trained meditators with people with between 10 000 and 54 000 hours of meditation practice in a Tibetan Buddhist method. Seven of the 12 experienced meditators were Asian, and they were compared with untrained Caucasian participants with an interest in learning to meditate. To be sure that this interest was not a confounding variable, a third group of participants were promised a financial incentive if their attention regions were most active. Participants' brains were scanned using fMRI while they concentrated on a dot on a screen in front of them and while at rest with no concentration. While they did this, researchers played various noises in an attempt to distract participants from their meditation and force them to work harder to sustain attention. Noises included a woman screaming, a baby cooing and restaurant background noise.

● Examiner's hint

The main learning outcomes associated with this section of the syllabus require you to show an understanding of how cognition and physiology can interact and how the environment and experience can affect the brain through neuroplasticity. Besides the empirical research in the boxes here, other studies in this chapter that can help you in this area include the case studies of H.M. and Janet. In some cases, it seems that brain damage has effects on cognition, and in others, cognition has effects on brain structure. Be clear about what each study shows.

It was expected that attention-related networks in the brain and the visual cortex would be more active during meditation than during rest periods, and novice meditators would find it more difficult than experts to sustain their concentration, so this effort would be observed on the fMRI. In addition, it was expected that experienced meditators would show less activation in areas of the brain associated with daydreams, emotional processing and other thoughts not relating to the task.

The results confirmed these expectations. The researchers noted the interesting finding that experienced meditators showed a response to the disturbing stimuli, not in terms of a change in attention away from the target of their concentration meditation, but in terms of some kind of adjustment of concentration, perhaps an active resistance to being disrupted.

The researchers believe that the differences observed are not related to age differences or possible brain differences relating to ethnicity or culture because they conducted statistical tests to eliminate these possibilities. Instead, they conclude that the differences are probably due to neuroplasticity, some kind of changes in the brain that have occurred over time as a result of periods of sustained meditation.

EXERCISE

4 **a** Briefly summarize this study under the headings *Aim*, *Method* and *Findings*.

b Is this a true experiment? How else could you describe the study?

c Are the conclusions valid?

EMPIRICAL RESEARCH

Changes in the brain after juggling training (Draganski et al. 2004)

These researchers were interested in determining whether both functional and structural changes could be detected in the human brain (using brain-imaging technologies) as a result of learning a new motor skill.

Twenty-one females and three males participated in the study, which required half of the participants to spend three months learning to perform a basic juggling routine for a minimum of 60 seconds. Structural MRI scans were done before and after the three months of practice, and a third scan was made three months later, during which time participants were not supposed to practise their new skills.

While there were no significant group differences in brain structure in the first scan (before training), two areas of the brain were significantly different in size after training. The difference became smaller in the third scan, when practice had ceased for three months. These differences were apparently due to an increase in volume in the two regions of the jugglers' brains, which are associated with the retention of visually detected movement information rather than physical co-ordination. Thus, the practice of watching balls moving through the air repetitively and learning to move in response to this has strengthened the connections between neurons in the parts of the brain responsible for this activity.

EXERCISE

5 **a** Briefly summarize this study under the headings *Aim*, *Method* and *Findings*.

b The researchers compared differences in the two groups before and after, rather than differences in individuals.

Can you think of any different ways they could have analysed their data?

c Do you think there are any problems with generalizing the results of this study?

EMPIRICAL RESEARCH

Changes in the brains of experienced London taxi drivers (Maguire et al. 2000)

It is known that animals which employ spatial memory seem to show morphological changes in the hippocampus (Figure 2.1). London taxi drivers must undertake special training that takes about two years to complete during which time they must learn the roads and routes to the extent that they can reliably navigate their way around the central area without the aid of a map. This learning period is referred to as being 'on the knowledge'. On the basis of all this information, Maguire et al. predicted that fully licensed London taxi drivers will have structural differences in their hippocampi as a result of this learning experience.

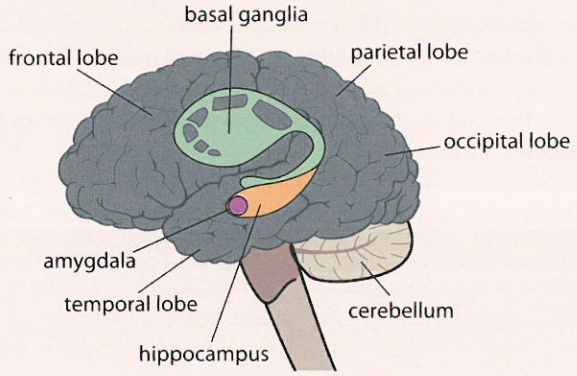


Figure 2.1
The location of the hippocampus within the brain.

To investigate this idea, the researchers used structural MRI scans of fully licensed male taxi drivers with a range of years' experience driving, and compared them with control subjects. The control subjects were not actual participants, but existing scans of healthy males who did not drive taxis.

They found that both the left and right hippocampi were significantly higher in volume in taxi drivers' brains, although there were some parts of the hippocampi that were smaller in taxi drivers. In addition, the researchers ran a correlation between volume of hippocampi and time spent as a taxi driver, and found a positive correlation that could not be accounted for by age differences. Maguire et al. conclude that there has probably been a redistribution of grey matter in the hippocampi as a result of intense development and use of spatial memory skills, specifically those relating to learning and remembering routes through the city. Again, this is likely to be a strengthening of connections between neurons in a well-used part of the brain.

EXERCISES

6 **a** Is this a true experiment? Why/why not?

b How trustworthy are the results of this study?

7 Maguire did further research on this topic. What kind of research is necessary to illustrate that the differences are genuinely caused by 'the knowledge'?

EMPIRICAL RESEARCH

PET evaluation of bilingual language compensation following early childhood brain damage (Tierney et al. 2001)

It has long been known that Broca's area in the left hemisphere of the frontal cortex plays an important role in speech production in the majority of healthy adults. Tierney et al. report the case of a 37-year-old man (MA) with normal speech function who was participating as a volunteer in a speech study when it was discovered that he had a lesion in his left frontal lobe, probably as a result of encephalitis he had suffered at the age of 6 weeks that had had no long-term, clinically significant consequences.

Both of his parents were deaf and he had used sign language at home from a young age. The researchers were curious to know if this might have had something to do with his ability to speak despite brain damage that should have prevented him from doing so..

The researchers compared MA and 12 control participants, who were also fluent in sign language, using PET scans while the participants produced narrative speech or signs. In addition, a set of motor control tasks were completed so that researchers could contrast movements required for sign language and speech with movement of the corresponding parts of the body without speech.

The researchers found that MA's right hemisphere was more active than control subjects' during the production of both speech and sign language. They also noted that he seemed more anxious and agitated, with more anger than the majority of participants. He was otherwise judged normal by independent observers of speech and sign language production, and according to scores on various neuropsychological tests. These findings suggest that language function seems to have developed in the right hemisphere instead of the left hemisphere as a form of adaptation following his early brain damage. This demonstrates the plasticity of the brain, especially during early childhood.

Further points of interest were that although the regions of the left hemisphere used by the controls during production of sign language were actually intact in MA, his right hemisphere still seemed to be responsible. At the same time, his visuo-spatial abilities were slightly below normal. These findings suggest that his language abilities may have developed in the right hemisphere at the expense of visuo-spatial ability.

Sign language requires the use of different parts of the brain: most deaf users of sign language use both sides of the brain: the language centres in the left and the visuospatial areas in the right.

EXERCISE

8 **a** How would you describe the method used in this study? What are the strengths and limitations of the study?

b Are there any practical implications of this study?

Environment and brain function

The studies in this section focus on how the brain changes in response to the way we use it. For example, highly practised meditating monks appear to have different levels of brain functioning because of the time they have spent meditating. The case study of MA shows how the brain can change in response to brain damage and new areas can take over the function of language if there is enough practice. The taxi drivers used their hippocampi to store more visual information than most people, so their brains appear to have adapted to their cognitive behaviour. And exercising the parts of the brain responsible for visual processing of movement is associated with changes in relevant regions of the brain. Remember, however, that you have identified strengths and limitations of the studies in this section, and it is important to question whether we can draw conclusions about causes and effects in terms of the interaction between cognition and physiology. MA's exposure to sign language is an example, and you will meet more examples throughout the book. This shows how important the environment is in shaping the structure of the brain and helps account for individual differences in brain structure and function.

2.5 Physiology and behaviour: Neurotransmission

Learning outcomes

- Using one or more examples, explain effects of neurotransmission on human behaviour.

How nerve cells communicate

One of the most important discoveries that have influenced psychology is the role of neurotransmission in behaviour, thought and emotion. Here, you will find that an understanding of how chemistry and biology work will improve your understanding of how humans think and act.

The brain is made up of an enormous number of neurons or nerve cells (Figure 2.2). Recent estimates suggest there may be as many as 100 billion in the human brain. The most important thing for you to understand about neuron structure is that they receive information from other neurons through their dendrites and transmit it (by electrical impulse) across the cell body and along the axon to the terminal buttons at the end. Most of what you need to know for the purposes of this course relates to the synapse, the gap between two neurons, which is where communication from one neuron to the next occurs.

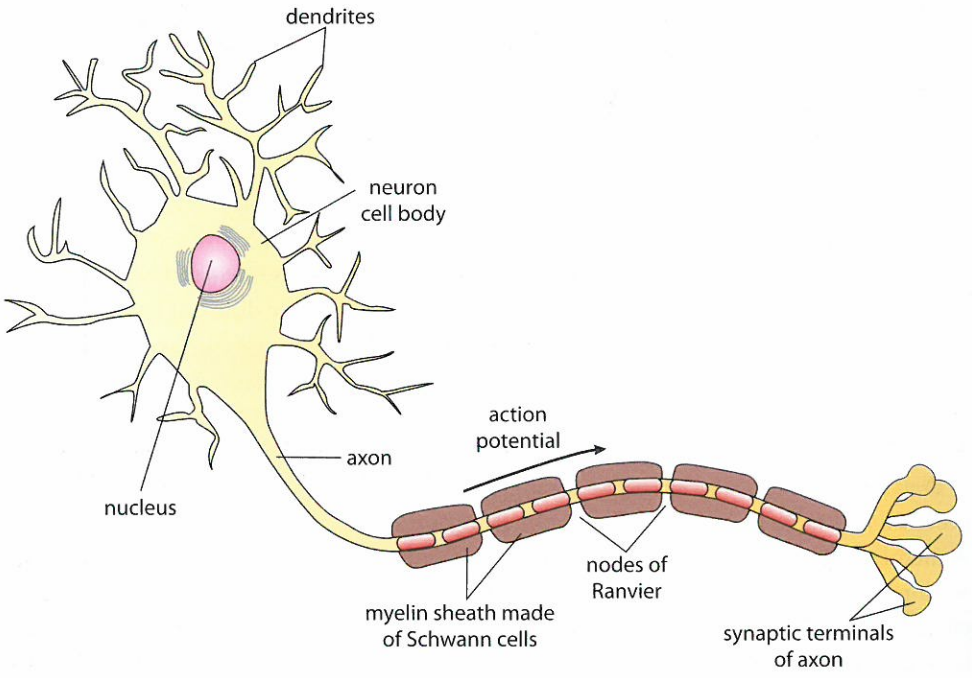


Figure 2.2
Structure of a neuron.

Communication *between* neurons is a chemical process; one neuron sends out chemicals known as neurotransmitters, and other neurons pick up the chemicals and may or may not send the message on. *Voluntary* movement of any muscle in the human body first requires the transmission of an 'instruction' to move through the appropriate parts of the brain and then to the muscle. The 'instructions' for *reflex* movements can be transmitted more rapidly because they usually involve the spinal chord and not the brain. Examples are the knee jerk test (when a doctor taps your knee) and the rapid removal of your hand from a

very hot object. At the biological level of analysis, *voluntary* movement can be viewed as the release of neurotransmitters in the primary motor cortex of the brain, triggering further communication through nerve cells until the appropriate muscles are activated to perform the movement.

Neurons are specific in which neurotransmitters they can release and receive. Neurons working with certain neurotransmitters can be found in greater or lesser concentration in certain parts of the brain. The primary motor cortex is populated by neurons that use dopamine and acetylcholine to communicate; the 'pleasure circuit' in the limbic system of the brain is populated by neurons using dopamine; neurons in the areas of the brain thought to be responsible for mood tend to use a chemical called serotonin.

To understand the effect of many of the drugs that have an effect on neurotransmission, it is important to note that there are three main parts to the transmission process at the synapse (Figure 2.3).

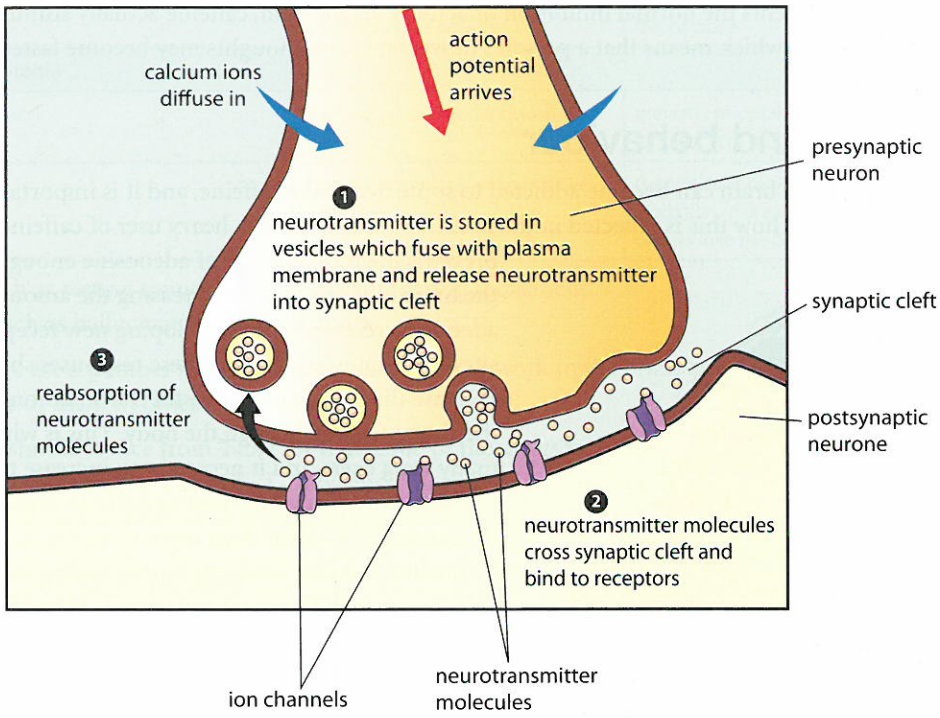


Figure 2.3
Chemical transmission at a synapse.

1 Neurotransmitters are stored in vesicles inside the terminal button of the axon; the vesicles are transported to the edge of the button and the neurotransmitters released into the synaptic gap.

2 In the synapse, neurotransmitters can bind with a receptor site on the next neuron if the receptor site is the right type of receptor and is vacant. This is often described by a lock-and-key analogy, in that the neurotransmitters are like keys, and can only fit into certain receptor sites in the same way that only the right key should open a lock. If enough of the neurotransmitter binds to the receiving neuron's receptor sites, the neuron will 'fire' – this means it transmits the information across its cell body electrically. When the information arrives at the end of the axon of this neuron, the chemical process is repeated.

3 Any unused neurotransmitter is eventually absorbed back into the neuron it came from (otherwise, enzymes will remove it from the synaptic cleft). This process is called reuptake. The neurotransmitter can then be used again.

Any of these three parts can be altered by drugs.

To learn more about synaptic transmission, go to www.pearsonhotlinks.com, enter the title or ISBN of this book and select weblinks 2.5a and 2.5b.

Long-term use of drugs causes structural change in the brain as it adapts to the altered activity of neurotransmitters. The most important effect of this adaptation is increased tolerance for the drug. This means that a person needs more of the drug to feel the same effect.

1 Certain drugs introduced to the nervous system can encourage or prevent the production and release of neurotransmitters thus increasing or decreasing the amount of neurotransmitter available in the synapse.

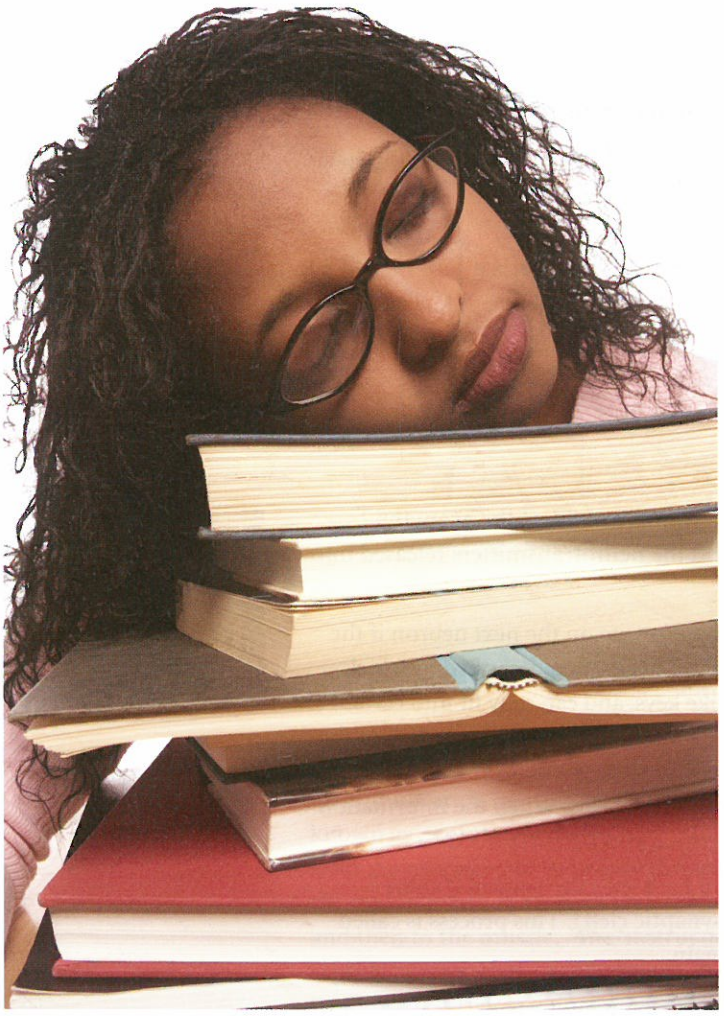
2 Certain drugs can occupy receptor sites that would normally receive a neurotransmitter. When a drug does this, it has its own effect on the receiving neuron as well as preventing the naturally occurring neurotransmitter from completing the intended communication.

3 Certain drugs can prevent the reuptake of neurotransmitters, which allows them more time to bind to receiving neurons.

Many people are familiar with the action of caffeine on the brain. Caffeine follows the second of the processes outlined above. When a person begins to feel sleepy, a neurotransmitter called adenosine is being released into the synaptic gap in a specific part of the brain. Adenosine acts to inhibit activity and prepare the body for sleep. When caffeine enters the synaptic gap, it binds with the receptor sites that adenosine normally uses, and prevents the normal inhibition of activity. In addition, caffeine actually stimulates brain activity, which means that a person's movements and thoughts may become faster.

Drugs and behaviour

Over time, the brain can become addicted to some drugs like caffeine, and it is important to understand how this is reflected in the brain. It is likely that if a heavy user of caffeine prevents the transmission of adenosine enough, the brain will respond by increasing the amount of adenosine released or by developing new receptor sites for adenosine. Both of these responses should increase the chance of successful transmission of the sleepy feeling through the body. This is why many drug users find it necessary to increase the amount of the drug they take in order to achieve the same effect – their drug use is compensated for by the brain. It also accounts for the feeling that coffee users may know, whereby a cup of coffee can prevent you from feeling sleepy for a limited time, but when this effect wears off, the sleepy feeling that arrives immediately afterwards can be quite overwhelming.



Sometimes, you fall asleep as soon as the caffeine effect wears off.

Biological researchers have investigated the effect of neurotransmitters on behaviour, and while some of their conclusions are only theoretical, others are based on having found a causal relationship through experimentation with animals and humans (Table 2.1).

TABLE 2.1 EFFECTS OF SOME DRUGS ON NEUROTRANSMISSION AND BEHAVIOUR

Neurotransmitter / drug	Result	Explanation (action on neurotransmission)
Acetylcholine (Ach)		
black widow venom	convulsions and death through exhaustion	over-stimulation of motor neurons resulting in uncontrollable excess movement
curare (a poison traditionally used in South America)	paralysis	inhibition of acetylcholine transmission, preventing muscle movement
Dopamine		
L-dopa	reduction of symptoms of Parkinson's disease*	triggers release of dopamine in areas of the brain that lack it, such as the motor cortex
anti-psychotic medication e.g. chlorpromazine	reduction of symptoms of schizophrenia**	reduces the amount of dopamine in the brain
cocaine	intense feelings of pleasure and faster cognitive activity	prevents re-uptake of dopamine, increasing the amount available in the synapse
Serotonin		
Prozac	improved mood in depressed people	prevents re-uptake of serotonin in the brain, allowing more successful regulation of mood
LSD	vivid hallucinations and a positive mood	theoretically, may bind with serotonin receptors and block the normal inhibition of dreams while the person is awake, allowing dreams to occur while the person is fully conscious

* such as resting tremor and difficulty initiating movement
** such as hallucinations and delusions

There are a number of other neurotransmitters at work in the brain and we will deal with some of them in other chapters.

You should notice from Table 2.1 that some of the drugs included act in apparently opposite ways. For example, L-dopa and chlorpromazine act by respectively increasing and decreasing the amount of dopamine present at the synapse.

Dopamine levels

L-dopa was a breakthrough in treatment for Parkinson's disease, a degenerative condition that usually involves a resting tremor, a difficulty initiating movement, and difficulty in controlling directed movement such as picking up a spoon or a cup. The drug was designed to relieve these symptoms because it was believed that increasing the amount of dopamine available would have a positive effect. It was initially very effective, but the effects do not usually last as the brain adapts to the presence of the drug. Other treatments have been developed more recently, such as the implantation into the brain of a device that can stimulate the release of dopamine in relevant areas, according to a patient's individual needs. This results in fewer side effects.

To learn more about implantation to control tremors, go to www.pearsonhotlinks.com, enter the title or ISBN of this book and select weblink 2.6.

Some evidence for the dopamine theory of schizophrenia comes from the discovery that patients who were overmedicated for Parkinson's disease started to develop some of the positive symptoms of schizophrenia, such as hallucinations and delusions. It had also been noted that individuals who were being medicated with tranquillizers that reduced the amount of dopamine available were less likely to experience these symptoms. In turn, overmedication with antipsychotic drugs was often found to lead to a condition known as tardive dyskinesia, which describes the same kind of movement problems found in Parkinson's disease. Thus it appears that there is a balance of dopamine required in individuals, and on one hand, too much dopamine can lead to symptoms of schizophrenia, while on the other hand, too little can lead to difficulties with movement.

Schizophrenia has been associated with high levels of dopamine; Parkinson's disease is associated with low levels of dopamine.

Prozac is a drug invented by Eli Lilly. It has been widely used as an anti-depressant. The active ingredient, fluoxetine, is also used in Sarafem, a drug to help with pre-menstrual syndrome.

Serotonin levels

A similar relationship can be seen between Prozac and LSD. Prozac was found to be effective in reducing symptoms of depression, theoretically because depression is associated with low levels of serotonin in specific regions of the brain responsible for mood regulation. Prozac's action of blocking serotonin reuptake is able to increase the amount of serotonin available and therefore facilitate the transmission of mood regulation messages in the brain.

The action of LSD has not been definitively established, but one theory is that it works against serotonin activity by blocking serotonin receptors. It seems that one of the main functions of serotonin is to inhibit dreaming while we are not sleeping. Bonson et al. (1996) used a questionnaire to discover that users of LSD who enjoyed its hallucinogenic effects but were diagnosed with depression and received antidepressants tended to find that although the depressive symptoms were reduced when the antidepressants began to take effect, a normal dose of LSD was no longer enough to give the same effect as it used to. The roles of serotonin and dopamine in abnormal psychological behaviour, cognition and emotion are discussed further in Chapter 5.

2.6 Physiology and behaviour: Hormones

Learning outcomes

- Using one or more examples, explain functions of two hormones in human behaviour.

Examiner's hint
You need to understand how two hormones work. Examples are provided here for three of the most well-known hormones: adrenaline, melatonin and oxytocin.

Hormones are chemical messengers that are secreted by glands and can have a widespread effect on both physiology and psychology in humans. The system of glands that releases hormones into the bloodstream is called the endocrine system.

Adrenaline

When this hormone is secreted, it has a number of effects on the human body. One general description of its effects is the **fight or flight response**; adrenaline prepares the body for action to help the organism deal with a threat, either by fighting it or by running away from it. Although we might associate adrenaline mostly with negative emotions such as fear, those who take part in 'extreme sports' know that exposing themselves to danger is thrilling, and the release of adrenaline in such situations appears to be associated with positive feelings.

In general, adrenaline increases the flow of oxygen and blood to the brain by increasing the activity of the heart and dilating blood vessels. It is sometimes used medically when a person has had a heart attack or a severe allergic or asthmatic reaction that prevents breathing. Other specific effects include an increase in heart rate and blood pressure, dilation of pupils in the eyes, and the transfer of key resources like oxygen and glucose away from internal organs towards the extremities of the body. Functions like digestion are less important in a stressful situation than being able to think and move quickly. Adrenaline is released from the adrenal medulla of the adrenal gland and increases alertness. It has been suggested that adrenaline might be responsible for the creation of emotion, and various studies have attempted to investigate the effect of this hormone on behaviour.

EMPIRICAL RESEARCH

Adrenaline and emotion (Schachter and Singer, 1962)

In this study, the researchers intended to challenge several theories of emotion. There has been a lot of debate regarding the origin of emotion, and this centred specifically on whether, on recognizing a threat:

- the brain automatically initiated the fight or flight response by releasing adrenaline, and the emotion of fear was a consequence of this increase in adrenaline

or

- the emotional state and the release of adrenaline were independent of each other, both caused by the brain at approximately the same time.

Schachter and Singer proposed that while adrenaline was able to cause emotion, the nature of the emotion caused was dependent on contextual factors. Moreover, they proposed that different emotions might be essentially the same set of physiological changes in the body that are labelled by the brain according to cognitive processing of the context.

To test this idea, they recruited volunteers to receive a vitamin injection and informed them that they would be participating in vision experiments. None of the 184 male participants received the injection they believed they were getting: three groups received an injection of adrenaline, and a fourth group received a placebo injection of saline solution. The three groups receiving the adrenaline injection were given different types of information about possible side-effects. One group were told that they might experience an increased heart rate and shaky hands (the actual effects of receiving an adrenaline injection). The second group were not given any information about possible side-effects. The third group were told that some people experienced a headache and numbness or itchiness in the feet as side-effects.

Thus, the first adrenaline group understood how their body would react and had an explanation of its cause, the other two adrenaline groups would inevitably experience the same physiological changes, but without explanation.

In order to manipulate the nature of the emotion experienced by participants, the researchers constructed two contexts:

- euphoria, in which a confederate of the experimenter encouraged the participant to join in games with office equipment in a waiting room
- anger, in which a confederate filled out a mock questionnaire at the same pace as the participant, but getting increasingly outraged by the increasingly personal nature of the questions.

The researchers used observational data based on structured observation of participants in each condition and then asked them to complete a self-report form that assessed their mood in terms of anger and happiness when they were finished.

In the euphoria condition, it was clear that the groups who had received an adrenaline injection without the correct information about its physiological effects showed more of the euphoric behaviours, and also reported more happiness on the self-report form.

Although the anger context did not elicit the corresponding pattern of reporting, the researchers suggested this might have resulted from discomfort in reporting anger compared to reporting happiness. They relied instead on behavioural data, which did show that participants who were aware of the real expected physiological changes performed less of the angry behaviours than the groups who had no explanation for their physiological arousal.

The researchers concluded that emotion occurs by a process of cognitive labelling: the interpretation of physiological cues is combined with contextual cues to construct a person's subjective experience of emotion.

EXERCISES

9 Summarize this study under the headings: *Aim*, *Method*, and *Findings*.

10 **a** What are the dependent and independent variables in this study?

b How valid are the researchers' conclusions? Justify your answer.

Melatonin

Melatonin is secreted when we are in the dark. It helps us to sleep.

Melatonin is a hormone with a role in the cycle of sleep. It is secreted from the pineal gland at the base of the brain. This gland is sometimes referred to as the third eye because of its ability to sense changes in light, a function more important in non-human animals.

In humans, the pineal gland relies on signals from the eyes and other sense organs relating to light and temperature for information about the time of day. It responds by secreting melatonin during darkness but not in light. One of the major actions of melatonin is to communicate with the pituitary gland, which then inhibits the secretion of many other hormones in the body that relate to states of wakefulness. Thus melatonin's role in sleep is to 'turn off' the body.

Seasonal affective disorder seems to be more common in northern climates with long, dark winters. However, the worst time of year for many (with an increased number of suicides) seems to be the spring. Some argue that the change to longer days upsets a person's system; others suggest that spring represents a new beginning, which reminds sufferers that the cycle is about to repeat itself.

Researchers have suggested that the phenomenon of seasonal affective disorder (SAD), may be related to melatonin levels. SAD is a type of depression related to the beginning and end of winter. In countries that experience a very short day when winter arrives, people have reduced exposure to daylight and may therefore have high levels of melatonin.

Avery et al. (2001) randomly assigned 95 SAD patients to three groups:

- one to receive dawn simulation (timed to begin at 4:30 a.m.)
- one to receive a more traditional bright-light therapy
- one to receive a placebo of a dim red light at dawn.

Using a structured interview that results in a depression-rating specific to this disorder, Avery et al. found that those who received traditional bright-light therapy or the placebo showed less improvement and more side-effects than the group who experienced dawn simulation. Members of the placebo group complained of insomnia significantly more than the other groups after four weeks of the study. This added to the conclusion that indeed the symptoms were related to a shift in the participants' sleep patterns: they found themselves in winter getting up before they were ready to wake because of a lack of light at their normal waking time. Bright-light therapy and dawn simulation were both able to help realign the sleep patterns with participants' lifestyles by encouraging the inhibition of melatonin secretion at an appropriate time, but dawn simulation was more likely to have positive therapeutic benefits and less likely to cause the side-effects of nausea and headache than bright-light therapy.

Lewy et al. (2006) note that the brain is sensitive to changes in the length of time that melatonin is released, so that as days become shorter and melatonin is released more, this is a signal to the brain to trigger other activity. Animals, for example, might enter hibernation or their breeding season in response to changes in the length of the night. Thus, SAD could be the result of an incompatibility between biological instincts and lifestyle. Lewy et al. tested their ideas in a similar way to Avery et al. (2001), but also administered low doses of melatonin to another group of participants in the evening. They found that sleep patterns and mood improved in participants who received this treatment, but that the improvements in mood were not as great as those experienced by those who received bright-light therapy in the morning.

Our understanding of the relationship between melatonin and the sleep–wake cycle has been useful when applied to help explain the phenomenon of jet lag. Jet lag occurs when

a person travelling in an aeroplane, usually from west to east across time zones, later experiences some of the same symptoms as SAD. These include feeling tired during the day, being unable to sleep at night, having low level of concentration, and disturbances in digestion and appetite. Again, this seems to result from an incompatibility between the information about time we receive from the environment (through exposure to light) and the information we have in our brain about what stage in our sleep–wake cycle we should be in. It seems that melatonin is not released in our brains at a time appropriate for the new location and we are, therefore, unable to sleep. Thus, we become tired at approximately the same time we would have been tired had we stayed in our original location. Over time, we do adapt to the new location. Our understanding of the sleep–wake cycle has provided two main aids to help us adapt:

- melatonin can be taken in pill form during the flight and on arrival at the destination to help reprogramme the brain to fit with our new location
- we can train ourselves to adapt to the new location by allowing ourselves to sleep only at specific times and for a limited amount of time while flying so that we are already prepared for our new destination when we get there.

Examiner's hint
This section helps explain the function of melatonin in the body and also, in terms of the relationship between light and the release of melatonin, deals with an effect of the environment on physiology.

Oxytocin

Oxytocin is sometimes known as the 'love hormone' or the 'trust hormone'. This refers to an early finding that oxytocin is released as a trigger for contractions in the uterus when a woman is giving birth. It is also released when a woman's nipples are physically stimulated, for example during breastfeeding. Before it was recognized that oxytocin might have a role in human social bonding, studies of animals indicated that it was involved in several forms of social attachment in mammal mothers. For example, in rats, oxytocin appears to lead to a shift in the mother's focus from grooming herself to grooming the rat pup (Pedersen and Boccia, 2003).

Oxytocin is sometimes thought to be the 'love hormone'.

In the case of animals and humans, it has been suggested that the function of this oxytocin is not only one of bonding, but also one of stress reduction. This makes good sense in light of the finding by Holt–Lunstad et al. (2008) that after an increase in positive physical contact between husband and wife, oxytocin levels rose and the husband's blood pressure decreased, which predicts other positive health outcomes.

Does massage affect oxytocin levels?

In another study, Morhenn et al. (2008) randomly assigned 96 students to a massage-and-trust, rest-and-trust, or massage-only group. The massage conditions consisted of 15-minute Swedish massages (a light massage which was shown to increase oxytocin levels in many people by Turner et al., 1999) while the rest condition required participants to rest for the same amount of time in the same room.

Participants then played a trust game that asked them to make a decision about how much money to give to another participant, knowing that this money would be tripled and there was a possibility that the other participant might share the profit. Sending a large amount of money was taken to indicate a high level of trust. Blood samples were taken twice, once at the beginning of their participation, and again close to their decision in the trust game, so that oxytocin levels could be measured.

The group that received only the massage were tested immediately following it. There was no significant change in their levels of oxytocin overall, although women were more likely to show increased levels.

Participants in the massage-and-trust group who made the decision about sending money to another participant sent $6.30 on average, only slightly more than the group who had simply rested without the massage.

To learn more about oxytocin, go to www.pearsonhotlinks.com, enter the title or ISBN of this book and select weblink 2.7.

However, the amount that the other participant sent back to the decision-maker was significantly different. Those who had been massaged sent back an average of $6.85. In addition, a positive correlation was found in participants who were sent money and the change in their oxytocin level, according to whether they had received a massage or simply rested.

If raised oxytocin levels increase trust, cooperation and bonding, is it wrong to attempt to use oxytocin for personal benefit?

The researchers concluded that while one episode of touch in the form of massage was not enough to raise oxytocin levels, the massage seemed to prime participants to sacrifice money when a stranger displayed trust towards them by sending them an amount of money – an act that they did not need to reciprocate, and an act accompanied by an increase in oxytocin. Thus, oxytocin levels are able to predict the amount of sacrifice the participants made in the trust game, suggesting that oxytocin's effect on behaviour is to increase generosity and cooperation among adults.

EXERCISE

11 Make a table summarizing the effects on behaviour of the three hormones examined using the column titles: *Hormone name*, *Behaviour affected*, *Example*.

2.7 Genetics and behaviour

Learning outcomes

- With reference to relevant research studies, to what extent does genetic inheritance influence behaviour?

Model of the double helix formed by the DNA molecule

The human being is one of many species that reproduce sexually. Sexual reproduction brings together genetic information from two parents in a fertilized egg. This accounts for a large number of inherited characteristics each new organism has. Knowledge of this mechanism existed before the discovery of the DNA molecule by Watson and Crick in 1953. It was perhaps most obviously observed in the breeding of dogs and horses, where breeders have for centuries been attempting to encourage stronger, faster, or more attractive animals to reproduce, in the knowledge that some of these characteristics would be passed on to their offspring.

Genetic information is contained in chromosomes, which are tightly wound strings of DNA present in every cell of the human body. What we call genes are groupings within the DNA of any chromosome. There are 23 pairs of chromosomes in every human cell (except egg cells and sperm). Each chromosome pair consists of one chromosome from each parent. Therefore there are two different sets of DNA, and therefore two different sets of genetic information. This means that genes also come in pairs, one gene on each chromosome of a chromosome pair.

Genes are thought to be responsible for the development of physical and behavioural characteristics. We refer to the genetic make-up of an individual as their genotype.

However, it has also been known for a long time that the genotype does not exclusively dictate the characteristics of any individual organism. There are a number of environmental influences such as diet and habitat that also influence the way an organism develops. The observable characteristics of an organism are known as the phenotype. Phenotype is the result of genotype and environment interacting.

You may have noticed that some fruit trees bear more fruit than others, sometimes because of access to sunlight. In 1948, Clausen et al. carried out a famous experiment that involved planting genetically identical yarrow plants at different altitudes. They found that the resulting phenotypes were quite different because of differences in the environmental conditions the plants were growing in.

Thus, when making conclusions about the role of genes in determining human behaviour and physical characteristics, it is essential to bear in mind that although some characteristics are strongly affected by genetic inheritance, it is not a simple causal relationship. There are a number of very broad, exaggerated and reductionist claims made in the media about the role of genes in human behaviour and you need to be able to think critically about these, in particular about the interaction between genotype and environment that occurs before we observe many human characteristics.

What does genetic information do?

One of the most famous examples of successful genetic research that has helped us understand human behaviour relates to a genetic condition called phenylketonuria (PKU).

If you check the ingredients on a packet of chewing gum or a diet soft drink, you might notice a warning that it contains phenylalanine, an amino acid present in artificial sweeteners. If you suffered from phenylketonuria, this would be important to you because you would not be able to produce the enzyme that metabolizes phenylalanine. Unlike most people who consume artificial sweeteners, those who have PKU build up a level of phenylalanine that eventually causes brain damage.

This is a good example of findings from genetic research for a number of reasons. First, the gene has been identified. Secondly, the role of the gene is clear. Thirdly, an intervention follows: in this case, abstinence from artificial sweeteners is recommended. Unfortunately, a lot of genetic research falls short of this example. A lot of such research is reported poorly in the media, resulting in a tendency for people to feel that genetic information has a stronger influence on their behavioural and physical characteristics than there is evidence for.

Examples of empirical research involving genes at the biological level of analysis are presented in the boxes overleaf.

In many countries, prenatal tests for PKU are the norm. The condition can be managed and its effects avoided.

EMPIRICAL RESEARCH

Is schizophrenia genetic? (Heston, 1966)

This was an adoption study. Adoption studies assume that if offspring are separated from their biological parents, we can conclude that any physical and behavioural similarities observed later between parent and child are largely caused by genetic factors.

Heston looked at the incidence of schizophrenia in children who lived in foster homes. He correlated this incidence with the diagnosis of schizophrenia in their biological mothers. The specific interest in this study was whether schizophrenia is genetic or not. If the condition were genetic, it would be expected that adoption would not affect the number of children who were later diagnosed with schizophrenia. But because of biological inheritance, a higher incidence of schizophrenia would be expected among the adopted children of schizophrenic mothers than among adoptees whose mothers did not have a diagnosis of schizophrenia. If nurture were more important, it might be hoped that adoption would reduce the number of children who were later diagnosed with schizophrenia, and the incidence would be approximately the same as among the other adoptees.

The incidence of schizophrenia in the general population is about 1%, and it was similar for those people who were adopted with no family history of schizophrenia. Heston found that over 10% of the adopted children with a family history of schizophrenia were later diagnosed with it. This is considered strong evidence that schizophrenia has a genetic component.

EXERCISE

12 **a** What problems are there with this type of research (adoption studies)?

b Are there any plausible alternative explanations for these results?

EMPIRICAL RESEARCH

Twin studies

Twin studies are a common research method at the biological level of analysis. For example, Bailey and Pillard (1991) studied monozygotic (MZ) twins and dizygotic (DZ) twins; they found a difference in concordance for homosexuality, measuring how often, when one twin was homosexual, the other one was also homosexual. DZ twins had a concordance rate of 22%, while MZ twins had a rate of 52%. These results indicate that although there must be some environmental influence to explain why the MZ twins did not have 100% concordance, there must also be a strong genetic component to explain why MZ twins have more than double the rate of concordance of DZ twins.

Santtila et al. (2008) carried out an enormous twin study in Finland using 6001 female and 3152 male twins and their siblings between the ages of 18 and 33. The researchers wanted to test the idea that reported rates of homosexuality might underestimate the frequency of homosexual attraction, and that it is more appropriate to study potential for homosexual response. This would allow for circumstantial changes in behaviour such as occur in prisons, in the military, and for profit in pornography.

The researchers asked twins to answer a questionnaire to establish sexual orientation, based on frequency of same-sex sexual contact during the preceding year. The participants were also asked to rate how likely it would be for them to agree to sexual intercourse with a handsome person of the same sex who suggested it, if nobody would know and it could be done on the participant's own terms.

Reported incidences of homosexual behaviour were 3.1% for men and 1.2% for women, but the potential for homosexual response was much larger, with 32.8% of men and 65.4% of women

suggesting there was some chance that they would agree in the situation described. Concordance rates for both the potential for homosexual response and overt homosexual behaviour indicated that there is probably a genetic component, with MZ twins more than twice as likely to answer the questions in the same way (Table 2.2).

TABLE 2.2 CONCORDANCE RATES FOR POTENTIAL FOR HOMOSEXUAL RESPONSE AND OVERT HOMOSEXUAL BEHAVIOUR AMONG MZ AND DZ TWINS

	Concordance rate for	
	Potential for homosexual response	**Overt homosexual behaviour**
Monozygotic male	0.534	0.380
Monozygotic female	0.526	0.594
Dizygotic male	0.234	0.000
Dizygotic female	0.264	0.000

Concordance rates can be expressed as a percentage (e.g. 52%) or as a number between 0 and 1 (e.g. 0.52).

The researchers considered that these results indicate that genes have a role in determining homosexual behaviour (even when they accounted for possible effects of a shared environment) and also that previous research into homosexuality has probably too narrowly defined homosexuality by focusing on overt behaviour rather than the potential for it.

EXERCISE

13 **a** Evaluate this research using your knowledge from the research methodology section.

b Are there plausible alternatives to the conclusion?

One of the problems with research like these examples is that it does not actually locate the gene or genes responsible, as occurred in the example of PKU given earlier. The more research is done into behavioural genetics, the clearer the picture is becoming: although genes have some role in influencing behaviour, they do not work in isolation from each other, nor in isolation from environmental factors. It appears in the case of behaviour that a set of genetic markers can be located and their biological function identified, but that environmental triggers are required for the behaviour to occur. This seems to be the case for a number of patterns of behaviour and disorders, including Alzheimer's disease, dyslexia, schizophrenia, and antisocial behaviour.

To learn more about genetic factors and behaviour, go to pearsonhotlinks.com, enter the title or ISBN of this book and select weblink 2.8.

So what conclusions can we make so far about the genetic influence on behaviour? It is fair to say that we know a lot more than we used to, and that we have a long way to go before we can make confident claims that our genetic inheritance determines our behaviour. Because research is not yet able to satisfactorily explain which genes are responsible for which behaviours and how this happens, we rely heavily on twin studies, adoption studies, animal models, and theoretical explanations of how and why behaviour might be inherited.

At the same time, however, it has become more and more important to understand the role of the environmental triggers. The diathesis–stress model is used in abnormal psychology (Chapter 5). It follows this basic principle: inherited factors can provide a vulnerability and environmental stimuli (like difficult life events) can interact to result in a disorder like depression.

For example, there appears to be a relationship between physical or sexual abuse in childhood and the development of antisocial behaviour and schizophrenia (Read et al., 2004). It is possible that differences in genetic vulnerability can explain why only some people are affected in this way. However, some argue that pursuing the causes of vulnerability should take a lower priority than addressing the triggers that we are increasingly certain about. Knowledge of only genetic vulnerability or only environmental triggers is usually insufficient.

● Examiner's hint

There are many genetic explanations for behaviour in the options chapters (Chapters 5–9). Use them to help you address the learning outcomes for this section.

2.8 Evolutionary psychology

Learning outcomes

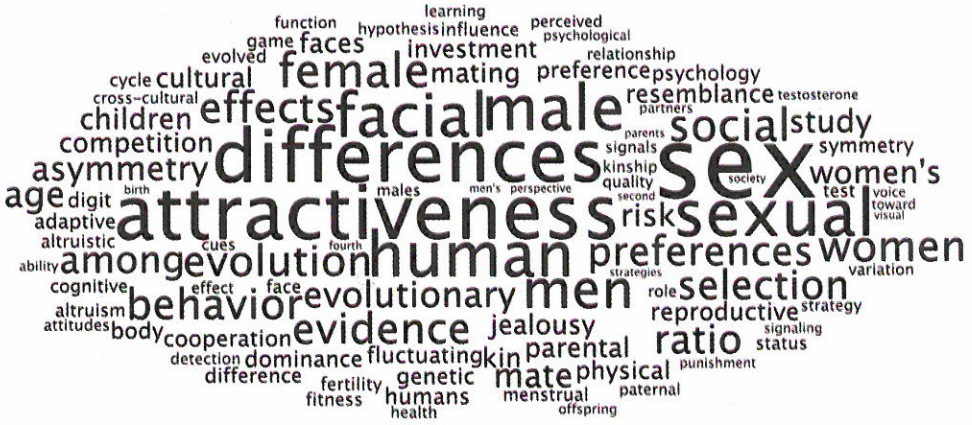
- Examine one evolutionary explanation of behaviour.

● Examiner's hints
In order to examine evolutionary explanations of behaviour, you must demonstrate an understanding of the assumptions underlying the explanation. Be sure you understand the basic principle of evolutionary explanations of behaviour outlined here.

This branch of psychology is based on some of the key principles of the biological level of analysis. If we assume (a) that a predisposition for certain behaviours is inherited and (b) that the principles of evolution dictate that genetically based behaviours of an individual who has reproduced are passed on (while genetically based behaviours of unsuccessful individuals are lost over time), then behaviours we observe today should have evolutionary explanations. In essence: if a behaviour exists in humans today, then it must in the past have helped human survival and reproduction. Behaviour that has helped a species survive and reproduce is described as adaptive. The key assumption of all evolutionary psychology research is that human behaviour must have been adaptive under some circumstances in the past.

While recorded history allows us to look back and make conclusions about similarities between behaviour now and in the past, it is clear that many evolutionary psychology offerings are guesswork at best. However, such arguments can help clarify many of the questions we ask.

The most popular topics of research in the journal *Evolution and Human Behaviour* are represented in this word-frequency cloud.



To access Worksheet 2.1 on an experiment in evolution with the silver fox, please visit www.pearsonbacconline.com and follow the on-screen instructions.

How could homosexuality be adaptive behaviour?

One of the potentially confusing issues with the twin studies into homosexuality outlined on page 60 is the question: How can homosexuality be genetically transmitted when it seems more likely to prevent reproduction?

Zietsch et al. (2008) provide a possible answer to this from an evolutionary psychology perspective. They consider several existing explanations; for example, that the presence of an individual homosexual person in the family offers some kind of reproductive advantage to others in the family – perhaps by sharing resources and care of others, thus increasing the reproductive fitness of the family, while not reproducing themselves.

Instead of such theories, however, Zietsch et al. investigate the idea that the genes which incline a man towards homosexuality are advantageous in a heterosexual man – perhaps somehow increasing his attractiveness to women. This idea is linked to other research which shows that women are more attracted to men with more feminine faces at certain times during their menstrual cycle.

To investigate this idea, the researchers mailed questionnaires to 4904 identical twins, asking them about sexual orientation, number of opposite-sex partners and gender identity. They found that sex-atypical gender identity (e.g. when a male feels he is more like a woman) is associated with having more heterosexual sex partners than others, and that this was exaggerated in a twin pair when one twin was homosexual – that is, the heterosexual twin brothers of homosexual men had a large number of sex partners. This is in line with the researchers' theory that when we inherit some of the genetic predisposition for homosexuality, but do not consider ourselves homosexual, we have inherited some characteristics normally associated with the opposite sex, and these somehow make us more attractive to members of the opposite sex. Men may, therefore, be attracted to women who have the stereotypically masculine features of competitiveness and sexual willingness.

Identical (monozygotic) twins share 100% of their genes.

Could homicide be adaptive behaviour?

Another example of an evolutionary psychology theory is the homicide adaptation theory (HAT). This theory suggests that humans today have evolved with some psychological adaptations for killing. It is logical that to be able to kill is a possible psychological advantage in an environment or context where killing is required (e.g. hunting) or is more likely to increase one's own chances of reproductive success (e.g. killing potential rivals or step-children, defending resources, or protecting one's own children from being killed).

Comparative psychology research has indicated that other species engage in killing behaviour within their species. This is considered to be an adaptation based on increasing their own or their offspring's chances of survival. It is therefore possible that humans carry a specific capacity for this behaviour, one that is reflected in the frequency of homicidal fantasies that occur in situations where murder might actually increase an individual's chances of reproducing, or their children's chances of surviving.

Durrant (2009) suggests that a possible weakness of this theory is the idea that some behaviours which have evolved over time are not adaptations to increase survival or reproductive success, but are by-products of evolution. So, perhaps homicide has no advantage.

To test a theory of evolutionary psychology, it is sometimes necessary to carry out a cost–benefit analysis. In this case, the advantages and disadvantages of killing are weighed against each other. If there are more costs than benefits, it seems unlikely that the behaviour is the result of successful adaptation. It has been argued, for example, that rape cannot be an adaptive behaviour as the costs outweigh the benefits. Durrant gives the example that attempting to kill will expose an individual to potential harm that might result in their own death, which is hardly adaptive, nor is the risk of being ostracized by a social group. He concludes that the HAT is unlikely to be correct.

This example of evolutionary psychology in action illustrates many of the problems with this branch of psychology. It is difficult to come close to proving that an evolutionary explanation is accurate, and that alternative explanations are not. Without being able to conduct experiments, it is impossible to establish cause–effect relationships, and it is therefore necessary to settle for the kind of correlational evidence used by Zietsch et al. (2008) above.

To learn more about evolutionary explanations of behaviour, go to www.pearsonhotlinks.com, enter the title or ISBN of this book and select weblink 2.9.

EXERCISE

14 **a** Browse the journal found through the Hotlinks box above and choose an explanation of behaviour. Summarize it and think about how convincing the explanation is.

b Is there any evidence for the claims made, and are there plausible alternatives?

Is there any way we can know if an evolutionary psychology explanation for behaviour is accurate?

2.9 Ethical considerations in research into genetic influences on behaviour

Learning outcomes

- Discuss ethical considerations in research into genetic influences on behaviour.

Genetic testing

To learn more about Huntington's disease, go to www.pearsonhotlinks.com, enter the title or ISBN of this book and select weblink 2.10.

In many countries in the world, certain genetic tests are considered normal and appropriate during pregnancy – this has helped to prevent many potential problems. For example, a test can be done during pregnancy to see if a baby has PKU; if it is positive, parents can be prepared to follow the special diet the baby needs right from the start so brain damage is prevented. It is also now possible to test for Huntington's disease, but there is no treatment.

But as we discover more about the role of genes in determining our behaviour and identify specific genes associated with risk for diseases and disorders, certain dangers emerge. Access to information about genetic heritage is at the core of ethical issues in this field. There are consequences for any individual who finds out that they have a genetic predisposition to a disorder or behaviour that they might consider unpleasant or harmful. There are additional problems if other parties are allowed to know, such as insurance companies who might prevent a person from receiving life insurance, or employers, who might refuse employment. For these reasons, genetic testing requires consent from the person involved or from the family members who are responsible for them. And everyone concerned should have access to counselling to deal with the consequences.

Who has the right to know if an unborn child has a genetic predisposition to a disorder that may develop in adulthood? Does it matter if there is no treatment yet available for the disorder?

Research findings

In the context of research, any information obtained about a participant should be accessible to the participant. This means that when a person participates in a study investigating the role of genes in any kind of behaviour, there is a risk that the person will learn something about themselves they are not prepared to deal with. Again, counselling should be offered as part of a full debriefing. In addition, it is often necessary to repeat the test to confirm the result as reporting inaccurate information could lead to a range of negative consequences.

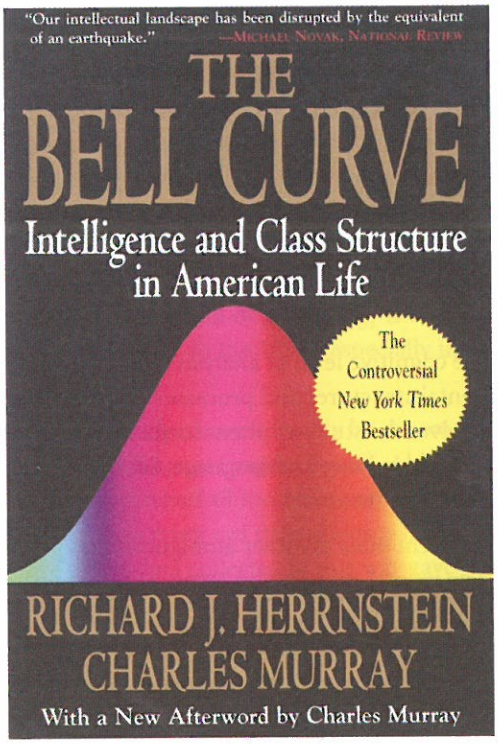
An alternative is to ensure that any data will be anonymously coded so that neither the researcher nor the participant knows which results match which specific DNA sample.

A further ethical issue is in the interpretation of research findings. When Richard Herrnstein and Charles Murray published a book called *The Bell Curve* in 1994, it caused widespread controversy. Their interpretation of research that demonstrated a difference in IQ scores between black and white Americans and between socio-economic groups led to a conclusion – widely reported and exaggerated in the media – that state money was being wasted on encouraging reproduction among low IQ groups and that investing money in education programmes for those with low access would not yield useful results as the differences in IQ are genetic.

Should governments invest in programmes to help increase IQ if it is genetic?

While the assumption that intelligence is partly genetic seems to have good support, none of the available research has sidelined the role of environmental factors.

This is an example of how researchers need to be careful that the conclusions they reach and report are valid and reliably demonstrated in the available research. In the case of genetic research, we are profoundly lacking in causal evidence due to a lack of the possibility to experiment for ethical reasons, and a lack of longitudinal research. The Human Genome Project completed a map of the human genome in 2000, and it can be expected that we will be treated to more and better-informed longitudinal studies based on the knowledge gained from the project in future. It is unlikely that it will ever become ethically possible to conduct genetic experiments with humans, so we will likely need to rely on data obtained from twin studies, adoption studies and longitudinal studies. The majority of these are correlational in nature, and therefore we are unlikely to have 100% certainty that genes in combination are entirely responsible for any human behaviour.



A highly controversial book: its title is derived from the bell-shaped normal distribution curve of IQ scores.

To learn more about the human genome project and advice on many ethical issues, go to www.pearsonhotlinks.com, enter the title or ISBN of this book and select weblink 2.11.

To access Worksheet 2.2 on methods used in the biological level of analysis, please visit www.pearsonbacconline.com and follow the on-screen instructions.

EXERCISE

15 Consider the material in this section and add any examples from the Human Genome Project website that demonstrate ethical issues.

PRACTICE QUESTIONS

To access Worksheet 2.3 with a full example answer to short answer question 4, please visit www.pearsonbacconline.com and follow the on-screen instructions.

To access Worksheet 2.4 with a full example answer to essay question 2, please visit www.pearsonbacconline.com and follow the on-screen instructions.

Short answer questions

1 Identify **two** hormones and, using examples, explain their function in human behaviour.

2 Describe **one** evolutionary psychology explanation of behaviour.

3 Explain **one** interaction between cognition and physiology.

4 Explain **one** study related to localization of function in the brain.

Essay questions

1 Discuss the use of brain imaging technologies in investigating the relationship between biological factors and behaviour.

2 Discuss ethical considerations related to research studies at the biological level of analysis.