UNIT 3

How does experience affect behaviour and mental processes?

AREA OF STUDY 1
How does the nervous system enable psychological functioning?

CHAPTER 2  Nervous system functioning
CHAPTER 3  Stress as a psychobiological process

AREA OF STUDY 2
How do people learn and remember?

CHAPTER 4  Neural basis of learning and memory
CHAPTER 5  Models to explain learning
CHAPTER 6  Process of memory
CHAPTER 7  Reliability of memory

OUTCOME 1
- explain how the structure and function of the human nervous system enables a person to interact with the external world and analyse the different ways in which stress can affect nervous system functioning
- apply biological and psychological explanations for how new information can be learned and stored in memory, and provide biological, psychological and social explanations of a person's inability to remember information
Key Knowledge

- the roles of different divisions of the nervous system (central and peripheral nervous systems and their associated subdivisions) in responding to, and integrating and coordinating with, sensory stimuli received by the body
- the distinction between conscious and unconscious responses by the nervous system to sensory stimuli, including the role of the spinal reflex
- the role of the neuron (dendrites, axon, myelin and axon terminals) as the primary cell involved in the reception and transmission of information across the synapse (excluding details related to signal transduction)
- the role of neurotransmitters in the transmission of neural information between neurons (lock-and-key process) to produce excitatory effects (as with glutamate) or inhibitory effects (as with gamma amino butyric acid [GABA])
- the effects of chronic changes to the functioning of the nervous system due to interference to neurotransmitter function, illustrated by the role of dopamine in Parkinson’s disease.

Roles of different divisions
Conscious and unconscious responses to sensory stimuli
Role of the neuron
Role of neurotransmitters
How interference to neurotransmitter function can affect nervous system functioning
The human nervous system is a complex, highly organised network of specialised cells that enables the brain to receive information about what is going on from both inside and outside the body and to respond appropriately. Everything you sense, feel, think and do is controlled by your nervous system in some way. This includes not only your everyday sensing, perceiving, learning, remembering, thinking, imagining, speaking, moving and the vast array of other responses you voluntarily make, but also your involuntary responses such as breathing, heart rate, squinting when someone turns on a bright light in the middle of the night, and the ‘butterflies’ you may feel in your stomach when anxious or meeting someone special.

The nervous system achieves this by serving as a communication system between the body's internal cells and organs and the external world. Through its vast network of nerves distributed throughout the body, the nervous system enables the brain to obtain information about what is going on inside and outside the body and to respond appropriately. Its three main functions are to:
- receive information
- process information, and
- coordinate a response to information.

Although the nervous system is a single body system, it is made up of different sub-systems. These are commonly referred to as ‘divisions’ or ‘branches’. Although each division carries out identifiable functions, the nervous system functions as a coordinated whole.

As shown in figure 2.1, the two main divisions are the central nervous system and the peripheral nervous system. They are connected by the spinal cord and constantly work together maintaining communication throughout the body, thereby enabling us to not only think, feel and act as we do, but also to keep us alive.

The brain is kept continually informed of the ever-changing external and internal environments of the body through sensory information received by the many and varied receptor cells located at or near the surface of the body and also deep within the body. These sensory receptors specialise in detecting and responding to different types of information.

Sensory information from the external environment is received through sensory receptors that are sensitive to specific types of stimuli arising outside the body. For example, neurons that function as sensory receptors at the back of the eye respond only to light for vision, the inner ear contains receptors for hearing, balance and body position, and the skin has receptors that are responsive to touch, pressure, temperature and pain. The nervous system also receives information from within various parts of the body. For example, sensory receptors located in the muscles, joints and tendons provide information about muscle tension, position and movement, and receptors located in internal organs such as the heart, lungs, liver and intestines provide information about the body's internal environment.

**Figure 2.1** The major divisions of the human nervous system
When the sensory information is received at the brain it is processed. This enables perception — interpretation of the sensory information so meaning can be assigned. Processing often involves integrating (combining) incoming information with other information already in the brain. For example, incoming auditory and visual sensory information may be combined with information stored in memory in order to recognise what was seen and heard. If required, the brain will also coordinate a response by initiating appropriate action; for example, by sending neural messages to muscles, glands and internal organs. This, in turn, enables muscles to move, causes glands to secrete (release) hormones and initiates the responses of internal organs, thereby enabling our body systems to function effectively.

Neurons and glial cells (or glia) are the building blocks of the nervous system. Basically, neurons are responsible for communicating information and glia support their functions. For example, some glia surround neurons to provide a coating (i.e. myelin) that insulates them, whereas others clear up debris that could interfere with efficient neural transmission.

In this chapter we examine the roles of different divisions of the nervous system in responding to, and integrating and coordinating with, sensory stimuli received by the body. We also explore how the specialised structures and functioning of neurons allow the nervous system to transmit neural information throughout all points of the body.

**ROLES OF DIFFERENT DIVISIONS**

**Central nervous system**

The central nervous system (CNS) comprises the brain and its extension, the spinal cord. Its main function is to process information received from the body’s internal and external environments and to activate appropriate responses.

**The brain**

The brain is an intricate network of cells that plays a vital role in processing information received through neural pathways from the body and in directing actions within the body. It continuously receives and analyses sensory information, responding by controlling all bodily actions and functions. Because of its crucial role in almost everything we think, feel and do, it is sometimes called the ‘control centre’ or ‘master regulator’.

The brain is more than a mass of networked cells. Brain cells are organised into many identifiable areas (or ‘regions’) and structures that have specialised functions. For example, some parts are dedicated to sensory or motor functions. Most parts, however, have integrating and overlapping functions. The apparently simple task of naming a familiar object, such as a car or mobile phone, will trigger activity in multiple structures and areas throughout the brain. These include areas at the back and side to process visual information received from the eyes, areas at the front, at the sides and near the centre to recover information from memory and to identify the object, and areas at the front involved in language and speech production to state the name of the object.

Many brain functions involve the activation of neural pathways that link different brain areas and structures. Neural pathways (also called tracts) comprise one or more circuits of interconnected neurons that form communication networks. Some span short distances and others extend from one side of the brain to the other. Neural pathways also connect the brain to other parts of the nervous system and the body. Although much is known about the brain’s neural circuitry, chemistry, structures and functioning, more remains unclear or unknown. For example, although it is known that different types of memory are associated with activity in distinctive parts of the brain, it is not fully understood how the brain goes about locating and retrieving specific memories when needed. Nor is it known exactly how different types of memories are actually stored.
The spinal cord

The **spinal cord** is the long, thin bundle of nerve tissue that extends from the base of the brain to the lower back. As can be seen in figure 2.3, the spinal cord links the brain and the parts of the body below the neck.

Two major functions of the spinal cord are to:
- receive sensory information from the body (via the peripheral nervous system) and send these messages to the brain for processing. For example, an itch on your big toe, the sensation of heat as you step into a warm bath and the pain of a sprained wrist are all carried via the spinal cord to the brain area responsible for initially processing this type of sensory information.
- receive motor information from the brain and send it to relevant parts of the body (via the peripheral nervous system) to control muscles, glands and internal organs so that appropriate actions can be taken. For example, to pick up a water bottle and bring it to your mouth for a drink, millions of neural messages are sent from the primary motor cortex to the muscles in your shoulder, upper arm, forearm, wrist and fingers. This is complemented by other relevant information that has been processed by your brain such as the size, shape, texture, weight, distance and location of the bottle in relation to your eyes, mouth and hand, so that you can successfully execute a highly coordinated series of individual movements performed in one, well-timed, smooth action with just enough pressure to grasp the bottle and hold it without squeezing it too hard.

The transmission of information along the spinal cord, to and from the brain, occurs through interconnected neurons that form nerve pathways. When the spinal cord is injured, the brain loses both sensory input from and control over the body. The severity of feeling loss and paralysis depends on where the spinal cord is injured. The higher up on the spine the injury is, the greater the number of nerve connections between the brain and body that are severed.

The spinal cord has a relatively simple organisation but does more than provide pathways for messages to and from the brain. It can also initiate some simple motor reactions in the form of reflexes that occur extremely rapidly, independently of the brain. We consider the function of *spinal reflexes* and how they occur in the next section.

**Figure 2.3** (a) The CNS consists of the brain and spinal cord. (b) Anatomically, the spinal cord links the brain and peripheral nervous system.
Peripheral nervous system

The CNS does not have direct contact with the outside world. It relies on the peripheral nervous system to link it to the rest of the body so that messages can be carried to and from the brain via the spinal cord.

The peripheral nervous system (PNS) is the entire network of nerves located outside the CNS. It extends from the top of the head, throughout the body to the tips of the fingers and toes, and to all parts of the skin. Its main function is to transmit information to and from the CNS. More specifically, the PNS:

- carries information to the CNS from the body’s muscles, organs, and glands (about the internal environment) and from the sensory organs (about the external environment);
- carries information from the CNS to the body’s muscles, organs, and glands.

The peripheral nervous system does this through its two subdivisions: the somatic nervous system and the autonomic nervous system.

**FIGURE 2.4** Some of the brain processes and information transmission via the spinal cord that occur to pick up a water bottle in one, well-timed, smooth action with just enough pressure to grasp the bottle and hold it without squeezing it too hard. Note that the right arm is picking up the bottle. This means that motor information will be sent from the brain’s left hemisphere (because it controls voluntary movements on the right side of the body) and somatosensory (‘body sense’) information will be sent to the brain’s left hemisphere.

**FIGURE 2.5** The peripheral nervous system (PNS) consists of all nerves outside the CNS. It carries information to and from the CNS.
BOX 2.1

Structure and function of brain areas
Neuropsychologists often describe the brain using three main areas (or regions) — the hindbrain, midbrain and forebrain. This is based on how the brain develops early in life. Each area is associated with identifiable mental processes and behaviour but these function in an integrated way to enable us to think, feel and behave as we do.

<INSERT FIG 2.6. IMAGE MUST BE LARGE>

FIGURE 2.6
**LEARNING ACTIVITY 2.1**

**Review questions**

1. **Describe three main functions of the human nervous system, with reference to examples not used in the text.**

2. **Which part of the nervous system coordinates the activity of the entire nervous system?**

3. (a) **Describe the two main functions of the spinal cord in terms of the types of messages that travel up and down its length, and the branch of the nervous system to which it connects.**
   
   (b) **What is a third function of the spinal cord?**

4. **Explain why spinal cord damage can result in loss of brain–body control.**

5. (a) **What is the peripheral nervous system?**

   (b) **What is its primary function?**

6. **Describe the relationship between the central nervous system and the peripheral nervous system, with reference to key functions of each division.**

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**LEARNING ACTIVITY 2.2**

**Reflection**

The term ‘peripheral’ means outlying or surrounding, suggesting lesser importance than the term ‘central’. With this in mind, suppose that your peripheral nervous system suddenly stopped ‘working’ for 30 seconds right now. Comment on your experience of the world during the 30 second period. What does this suggest about the importance of the PNS?

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**Somatic nervous system**

The **somatic nervous system (SNS)** is a network of nerves that carry sensory information to the CNS and motor information from the CNS. Sensory information is received at sensory receptor sites in the body (skin, muscles, joints and tendons) and carried along sensory neural pathways by sensory neurons. Motor information is carried along motor neural pathways by motor neurons to skeletal muscles to control their activity by causing them to contract or relax. Skeletal muscles are attached to our bones and respond to messages from the CNS to initiate, change or stop movement.

The sensory information is called afferent and the motor information efferent. These terms refer to the direction of the neural information flow. More specifically, **afferent** information is sensory information coming into the CNS (incoming information), whereas **efferent** information is motor information leaving the CNS (outgoing information).
LEARNING ACTIVITY 2.3

Review questions

1. (a) Briefly describe the two main functions of the somatic nervous system.
   (b) Give an example of each of these functions, using examples not referred to in the text.

2. Distinguish between the afferent and efferent information with reference to the type of information and the direction in which it is transmitted.

3. Whenever you reach to pick up a glass of water on a table, both the sensory and motor functions of the somatic nervous system are involved. Explain both the sensory and motor roles in grasping the glass.

4. This athlete has restricted movement due to paraplegia caused by spinal cord damage. Explain the athlete’s restricted movement with reference to the somatic nervous system.

The autonomic nervous system

The autonomic nervous system (ANS) is a subdivision of the PNS that connects the CNS to the body’s internal organs (such as the heart, stomach and liver) and glands (such as sweat, salivary and adrenal glands), providing feedback to the brain about their activities. The ANS is called ‘autonomous’ because many of the organs, glands and processes under its control are self-regulating and therefore occur without conscious effort and are not usually under our voluntary control. For example, your heartbeat, breathing, digestion and perspiration occur without you consciously activating or controlling them.

While skeletal muscles are completely inactive in the absence of motor neuron messages from the brain, the muscles involved in the activity of internal organs and glands (called visceral muscles) have built-in mechanisms for generating activity and do not depend on voluntary control by the brain. This is an important feature of the ANS, as it functions continuously — whether we are awake, active, asleep, under an anaesthetic or even in a coma. Regardless of our level of awareness or alertness, the ANS keeps the vital organs and systems of our body functioning, thereby maintaining our survival.

Unlike the somatic nervous system, which is responsible for initiating skeletal muscle movement, the ANS regulates the activity of the visceral muscles, organs and glands. Thus the messages carried between the CNS and the visceral muscles, organs and glands either increase or decrease their respective activities in response to the varying demands placed on the body throughout each day.

You often become consciously aware of ANS functions when you experience emotions such as fear, anger and excitement at intense levels because this is when there is heightened ANS
activity. For example, think about how you can feel your heart and breathing rates change when you suddenly become very frightened, or during exhilarating moments on a roller-coaster ride. Recall also the physiological changes you can instantly feel when the fear or exhilaration start to diminish. Your heart rate noticeably slows and your breathing becomes more regulated. Any goosebumps or feelings of butterflies in your stomach will also eventually disappear.

The ANS is not completely self-regulating. It is linked to the brain’s cerebral cortex so we can voluntarily control a few autonomic responses at certain times. For example, with conscious effort, you could control your breathing rate right now.

Some people are able to use techniques they have learned to exercise extraordinary control over specific autonomic responses. For example, it has been reported that some Hindu holy men in India who are highly skilled yoga practitioners have been able to increase their heartbeat from the normal resting rate of 75 beats or so per minute to 300 per minute without undertaking any physical activity, or have slowed their heartbeat to less than 50 beats per minute. Some have also been reported as being able to control their body temperature to the extent that one side of their hand is warm while the other side is cold (Blanchard & Young, 1973; Pines, 1973).

People who aren’t yogis can also learn to control various specific autonomic responses using a technique called biofeedback training. Biofeedback is a process by which a person receives information (‘feedback’) about the state of an internal bodily activity that normally occurs automatically, and then uses thought processes to exert control over that activity. The person learns a strategy, such as relaxation and/or visualisation, in order to control a particular autonomic response. Feedback about the state of the autonomic response being controlled is usually provided by a monitoring device connected to the person.

**Figure 2.9** In outer space, the temperature is extremely cold and there is no oxygen. Astronauts wear special space suits to restrict heat loss and to maintain adequate oxygen pressure for brain function. On Earth, these functions occur automatically through the activity of the autonomic nervous system.

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**LEARNING ACTIVITY 2.4**

**Review questions**

1. (a) Explain why the autonomic nervous system is described as autonomous.
   (b) Is ‘autonomous’ a truly accurate term for describing this nervous system? Explain with reference to an example.

2. Explain the relationship of the autonomic nervous system to the central nervous system with reference to a physiological response.

3. What is a key difference between skeletal muscles and visceral muscles?

4. Which is more important in maintaining our survival: the autonomic nervous system or the central nervous system? Explain with reference to an example.
LEARNING ACTIVITY 2.5

Distinguishing between the somatic nervous system and the autonomic nervous system

Complete the following table to indicate which division of the peripheral nervous system is more likely to be involved in each of the following responses: the somatic nervous system (S), the autonomic nervous system (A) or both (B)?

- pressing a key to send an email
- eating dinner
- sweating before having to give an important speech
- clenching your fists while watching a scary movie
- crouching on the blocks awaiting the starting siren before swimming in a 50-metre freestyle final
- washing the dog
- blinking
- talking on the phone
- laughing at a joke
- heart races when you are startled by a loud noise

<table>
<thead>
<tr>
<th>Response</th>
<th>somatic nervous system (S), autonomic nervous system (A), both (S &amp; A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Divisions of the ANS

The ANS consists of two distinct divisions that complement ('balance') each other, but generally have opposite effects. These are:

- the sympathetic nervous system, which is responsible for increasing the activity of most visceral muscles, organs and glands in times of vigorous activity, stress or threat
- the parasympathetic nervous system, which is responsible for decreasing the activity of most visceral muscles, organs and glands, and restoring body functioning to its normal state.

The complementary actions of the sympathetic and parasympathetic nervous systems occur without conscious effort and are demonstrated when you engage in an activity requiring physical exertion over a period of time. For example, when playing tennis vigorously, your sympathetic nervous system speeds up your heart rate to pump more blood and oxygen to your muscles. It causes your liver to release sugar into your bloodstream for energy, and induces sweating to keep your skin cool and prevent you from overheating. Because the body is pumping more blood and oxygen to the muscles, these are diverted from non-essential functions such as digestion, so this is inhibited. After the game, your parasympathetic nervous system takes over. Your heart rate slows, constricting the blood vessels in your muscles so the blood flow is diverted to the internal organs. Your sweat glands gradually slow down the production of sweat as the body returns to its ‘normal’ state.

The sympathetic and parasympathetic nervous systems do not function in an ‘on/off’ or ‘either/or’ way. They are both active at the same time. However, one system is usually dominant at any given time. For example, the sympathetic division dominates and is more active during emotional arousal, whereas the parasympathetic division is dominant and more active during rest and digestion.

The sympathetic nervous system

The sympathetic nervous system activates internal muscles, organs and glands to prepare the body for vigorous activity or to deal with a stressful or threatening situation. It is activated by a stressor or fear stimulus and enhances survival by providing an immediate response, in a split second, to any kind of emergency.

When you perceive an emergency or experience a crisis, the sympathetic nervous system activates specific organs and glands to respond. Glands that are activated include the adrenal glands, which are located just above your kidneys and release hormones (such as adrenaline) into the bloodstream. These circulate throughout your body, enhancing the effects of the sympathetic nervous system by activating various muscles, organs and other glands in preparation for dealing with the stressor or potential threat.

The result is that your heart rate and blood pressure increase, and your breathing rate increases so more oxygen can be taken in. Sugar and fat are released from storage to provide instant energy to the skeletal muscles. Your pupils dilate (‘expand’) to allow more light to enter the eye and enhance vision. Your sweat glands increase production of sweat to cool the body. In addition, digestion is slowed down. The sympathetic nervous system is also involved when you blush or get goosebumps, making the hairs on your body stand on end (see box 2.2).
Box 2.2

**Goosebumps**

Goosebumps appear when the fine hairs on your skin stand on end. Their appearance is controlled by the sympathetic nervous system. Human body hairs are so short that when they become erect, nothing much happens. The response of goosebumps has been described as an evolutionary response linked to our ancient ancestors, who had hairier bodies. Erecting the hairs helps non-human mammals conserve their body warmth in a cold environment by increasing insulation around their bodies. In several species it also serves as a defence against enemies in emergency situations. Consider, for example, a frightened cornered cat. By erecting its hairs, it looks larger and by doing so may deter its opponent.

The echidna’s quills, which are an effective defence against potential predators, are actually modified body hairs. In an emergency situation, sympathetic nervous system activity leads to erection of the quills, just as it leads to erection of hairs in other mammals. The behaviour that makes the quills so useful (their erection in response to fear) is said to have evolved before the quills themselves did.

The parasympathetic nervous system

In times of minimal stress and in the absence of threat, the **parasympathetic nervous system** helps to maintain the internal body environment in a steady, balanced state of normal functioning. The parasympathetic nervous system generally has the effect of counterbalancing the activities of the sympathetic nervous system. It restores the body to a state of calm, once the need for sympathetic nervous system activation has passed.

The parasympathetic nervous system dominates the sympathetic nervous system most of the time. It is involved in routine, everyday activities. For example, when you eat, the parasympathetic nervous system stimulates the stomach and intestines to digest food. It is also involved in the elimination of wastes and the protection of the visual system through the production of tears and through automatic pupil constriction in conditions...
of bright light. In addition, when returning the body
to a balanced state, the parasympathetic nervous system reduces heart and breathing rates, and
minimises the release of sugar (glucose) and fats into the bloodstream.

If you had to jump out of the way of an oncoming
car, your sympathetic nervous system would
immediately be activated. Once the danger had passed,
your parasympathetic nervous system would take over
and the various bodily systems and functions activated
by the sympathetic nervous system would gradually
begin to return to normal. The parasympathetic
nervous system takes longer to return the body to its
normal state compared with the sympathetic nervous system's immediate activation. This is because of the
lingering presence of the hormones that are released
when the sympathetic nervous system is activated.
They remain in the bloodstream for some time after
the threat has passed.

**TABLE 2.1** The activities of the sympathetic and parasympathetic nervous systems

<table>
<thead>
<tr>
<th>Bodily organ</th>
<th>Bodily function</th>
<th>Sympathetic nervous system action</th>
<th>Parasympathetic nervous system action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils</td>
<td>Regulate the amount of light entering the eye</td>
<td>Dilate (expand)</td>
<td>Contract</td>
</tr>
<tr>
<td>Salivary glands</td>
<td>Digestion</td>
<td>Decrease salivation</td>
<td>Increase salivation</td>
</tr>
<tr>
<td>Heart</td>
<td>Pumps blood</td>
<td>Accelerates heart rate</td>
<td>Slows heart rate</td>
</tr>
<tr>
<td>Bronchioles of lungs</td>
<td>Breathing</td>
<td>Dilate (expand)</td>
<td>Contract</td>
</tr>
<tr>
<td>Stomach</td>
<td>Digestion</td>
<td>Decreases contractions</td>
<td>Increases contractions</td>
</tr>
<tr>
<td>Liver</td>
<td>Produces bile to aid digestion Maintains blood sugar (glucose) level</td>
<td>Increases the release of glucose (sugar)</td>
<td>Decreases the release of glucose (sugar)</td>
</tr>
<tr>
<td>Gall bladder</td>
<td>Stores bile</td>
<td>Inhibits the release of bile</td>
<td>Stimulates the release of bile</td>
</tr>
<tr>
<td>Adrenal glands</td>
<td>Secrete the hormones adrenaline (epinephrine) and noradrenaline (norepinephrine) from the medulla</td>
<td>Stimulate hormone secretion resulting in increased heart rate, blood pressure and breathing rate, and relaxation of intestinal muscles</td>
<td>Inhibit hormone secretion</td>
</tr>
<tr>
<td>Bladder</td>
<td>Stores urine</td>
<td>Relaxes</td>
<td>Increases contractions</td>
</tr>
<tr>
<td>Intestine</td>
<td>Digestion</td>
<td>Relaxes</td>
<td>Increases contractions</td>
</tr>
<tr>
<td>Genitals</td>
<td>Reproduction</td>
<td>Excite</td>
<td>Relax</td>
</tr>
<tr>
<td>Sweat glands</td>
<td>Regulate temperature</td>
<td>Increase production of perspiration</td>
<td>Decrease production of perspiration</td>
</tr>
</tbody>
</table>

**FIGURE 2.12** Riding on a roller-coaster activates the sympathetic nervous system. After the ride is over, the parasympathetic nervous system restores the body to a state of calm.

**LEARNING ACTIVITY 2.6**

**Review questions**

1. In what main way do the sympathetic nervous system and the parasympathetic nervous system differ?
2. (a) What is the role of the sympathetic nervous system in enhancing survival?
   (b) Give three examples of bodily functions that increase their activity as a result of sympathetic nervous system activation.
   (c) Give three examples of bodily functions that decrease their activity as a result of sympathetic nervous system activation.

3. (a) Describe the main roles of the parasympathetic nervous system.
   (b) Give three examples of bodily functions that are affected as a result of the action of the parasympathetic nervous system. Briefly explain the purpose of these changes if resulting from parasympathetic nervous system activation.

4. Explain why it can take longer for the parasympathetic nervous system to ‘slow down’ bodily functions than it does for the sympathetic nervous system to ‘speed up’ bodily functions.
LEARNING ACTIVITY 2.7

Sympathetic versus parasympathetic nervous systems

1 Which division of the autonomic nervous system is likely to be dominant if you are in each of the following situations?
   (a) lying on the beach reading a book
   (b) waiting for the delivery of your VCE results
   (c) feeling anxious about a blind date
   (d) hearing an unexpected loud knock on the window at 2 am while watching TV alone
   (e) eating dinner
   (f) watching a terrifying scene in a movie
   (g) sitting in class listening with interest to a teacher’s explanation.

2 Which division of the autonomic nervous system is likely to be dominant when each of the following physiological responses is observed?
   (a) increased rate of digestion
   (b) decreased salivation
   (c) increased pulse rate
   (d) decreased pupil size
   (e) increased perspiration.

LEARNING ACTIVITY 2.8

Summarising the activities of the sympathetic and parasympathetic nervous systems

Copy the diagram below, then summarise the activities of the sympathetic and parasympathetic nervous systems. Insert your answers on the lines connecting the various organs and glands, as shown in the example for the pupil.

Diagram:

- Central nervous system
- Sympathetic nervous system
- Parasympathetic nervous system
- Pupil
- Salivary glands
- Lungs
- Heart
- Intestine
- Stomach
- Pancreas
- Gall bladder
- Liver
- Kidney
- Adrenal gland
- Bladder
CONSCIOUS AND UNCONSCIOUS RESPONSES TO SENSORY STIMULI

Some people believe that we use only 10% of our brain and the rest is a huge reservoir of untapped potential for some kind of remarkable ‘power’. The reality is that we ordinarily use virtually every part of the brain, and that the brain is active almost all the time. In neurosurgery, where it is possible to observe the functions of a patient’s brain under local anaesthetic while the patient is awake, electrical stimulations in virtually all parts show activity at the neuronal level, even when no sensory experience, movement or any other reaction is being observed. Moreover, no areas of the brain are completely inactive, even during sleep. If they were, it would indicate a serious functional disorder (CERI, 2007; Horstman, 2009; Kolb & Whishaw, 2014).

Our brain and nervous system are constantly processing sensory stimuli detected by sensory receptors and organs that respond to the different types of information received from both our internal and external environments. Our responses to these internally and externally sourced stimuli may be conscious or unconscious. Psychologists distinguish between these reactions primarily in terms of whether or not there is awareness.

A conscious response to a sensory stimulus is a reaction that involves awareness. You will have paid attention to the stimulus and therefore know about it. The response will usually be a voluntary, ‘intentional’ reaction. The reaction, even if momentary, is also likely to be goal directed (‘purposeful’) and you will be able to exercise some degree of control over it.

In the course of a typical day we make numerous conscious responses of varying complexity to all kinds of external sensory stimuli that bombard our senses. For example, when you step outside and feel the air temperature you will make a conscious response when you decide whether to put on a jacket. Similarly, if the sun is shining brightly, you may choose to wear sunglasses, a hat or both.

A conscious response may also be made to an internally sourced stimulus, as might occur if you feel a stomach ache in class at school. Depending on the severity of the ache, you may decide to ignore it, stroke your stomach, tell someone about it, excuse yourself and leave the room, or react in some other way that you believe is best.

An unconscious response to a sensory stimulus is a reaction that does not involve awareness. It is involuntary, unintentional, automatic and we cannot ordinarily control its occurrence. Bodily responses regulated by the ANS occur automatically without conscious effort. For example, in response to stimuli about the state of different bodily systems, your ANS is unconsciously regulating their functioning, pumping blood from your heart, digesting your food and so on. You don’t consciously have to think about making your heart beat, your eyes blink or your lungs fill with oxygen. Many of these ANS functions are actually reflexive responses (called autonomic reflexes).

Other reflexive responses also serve to help us avoid danger and minimise harm. Sometimes, we need to react so quickly that there is no time for conscious thought. These unconscious, automatically occurring responses are reflexes involving contraction of skeletal muscles. Most are very simple responses. They occur in the same way each time and do not require learning. We consider the role of the spinal reflex.

The spinal reflex

The spinal cord does more than provide pathways for messages to and from the brain. It can also initiate some simple responses on its own independently of the brain. These responses include spinal reflexes.

A spinal reflex is an unconscious, involuntary and automatically occurring response to certain stimuli without any involvement of the brain. It is often referred to as a reflex arc because the response to an incoming stimulus is automatically ‘reflected back’ from the spinal cord without any initial input from the brain and before the brain processes a conscious perception of the stimulus.

For example, if you were to touch the hot handle of a frying pan, you would automatically withdraw your hand to release the handle before the sensory information travels all the way to your brain and therefore before pain is actually experienced. The sensory receptors in your finger would send messages to your CNS, but the first point of contact in the CNS is the spinal cord. It responds with a message via motor
neurons to move the appropriate muscles in your hand to release the hot object and withdraw the hand.

The immediate response at the spinal cord enables a faster reaction time, a fraction of a second before the sensory information reaches the brain. Consequently, a spinal reflex involving a withdrawal reaction is believed to be an adaptive response. The spinal reflex is adaptive in that it saves time in a situation that may be very harmful to the organism. When a spinal reflex occurs, the spinal cord responds to the message directly, before the message is carried further on to the brain. While the transmission of information from the spinal cord to the brain only takes a fraction of a second, this saved time may be important in terms of minimising harm, or even saving the life of the organism. Other examples of this type of spinal reflex are when you jerk your bare foot up from the hot pavement and when you withdraw your hand if you touch a sharp rose thorn or needle.

Because reflexes are normally so predictable they provide useful information about the functioning of the nervous system, and greatly assist in the diagnosis of neural disorders. Damage or disease anywhere along its reflex arc can cause a reflex to be absent or abnormal. For example, when the knee is tapped on the patellar ligament, the sensory nerve that receives this stimulus carries the information to the spinal cord, where it is relayed to a motor nerve. This normally causes the quadriceps muscle at the front of the thigh to contract and jerk the leg up. The leg begins to jerk up while the brain is just becoming aware of the tap. Absence of this patellar reflex could indicate damage within sensory or motor pathways, or a spinal cord injury in the lower back area (Jenkins, Kemniz & Tortora, 2010).

The spinal reflex demonstrates that a response to a particular sensory stimulus can have both an unconscious and conscious component, one occurring before the other. For each reflex action, a handful of neurons simply convert a sensori stimulus into action. These neurons are shown in figure 2.14. We consider their specific roles in the next section.

**FIGURE 2.14** This sequence shows a spinal reflex involving a withdrawal response. Sensory receptors respond to the stimulation and initiate a neural message that is carried by sensory neurons to interneurons in the spinal cord. Interneurons act as a link between sensory and motor neurons, relaying information from one to the other (because sensory and motor neurons rarely ever connect directly). The interneurons send the message to motor neurons that carry a message back to the appropriate muscles, causing them to contract and pull away from the stimulus. The spinal cord will also carry the message to the brain, including information about the action taken. The hot and potentially harmful saucepan handle is released before the brain processes the conscious perception of pain.
LEARNING ACTIVITY 2.9

Review questions
1. (a) Distinguish between a conscious and unconscious response by the nervous system to a sensori-stimulus with reference to three key points.
   (b) Give an example of when you may respond to an external stimulus before you know that you have responded.

2. Formulate a definition for a reflex.

3. (a) Explain what a spinal reflex is.
   (b) Why is it also called a reflex arc?
   (c) Why is a spinal reflex considered to have an ‘adaptive’ or ‘survival’ role?
   (d) Give an example of a reflex response that you believe may not be involved in a spinal reflex arc.

   Explain your choice of example.

4. Draw a simple flow chart to name the three types of neurones involved in a spinal reflex and show the sequence in which they contribute to the response.

5. How might damage to interneurons affect the spinal reflex?

6. Sam is using a wet knife to remove a broken piece of toasted bread that is jammed in the toaster. She experiences an electric shock and spontaneously releases the knife and pulls her hand away from the stimulus.
   (a) Will Sam experience pain? Explain your answer.
   (b) List, in their correct order, the steps that enabled Sam’s spinal reflex.

LEARNING ACTIVITY 2.10

Visual presentation
Barefooted Jake steps on the sharp end of a drawing pin and immediately jerks up his foot before completing the step.

Create a flow chart which outlines the sequence of events in Jake’s spinal reflex response and refers to the relevant anatomical features.

You may present your flow chart in a digital format, for example, as a Powerpoint slide with SmartArt graphics. The flow chart may include a copy of the stimulus event shown above.

LEARNING ACTIVITY 2.11

Main divisions and subdivisions of the human nervous system

Complete the following chart to show the main divisions and subdivisions of the human nervous system.
ROLE OF THE NEURON

The human nervous system consists of billions of neurons and glial cells. The neuron is the primary cell involved in the reception and transmission of information throughout the nervous system and different types of glial cells support neuronal function.

When even one part of the process breaks down, the results can be devastating. Many brain disorders and nervous system diseases, including schizophrenia, Alzheimer's disease, Parkinson's disease, epilepsy, multiple sclerosis and even botulism that causes paralysis, have been linked to problems with neurons and communication within and between neurons. Glial cells are also implicated in most neurological disorders and diseases given their numbers and crucial roles (Fields, 2011; Miller, Cookson & Dickson, 2004).

A neuron is an individual nerve cell that is specialised to receive, process and/or transmit information. Neurons not only communicate with each other, but also with muscles and glands. They are the building blocks of the brain and nervous system. The entire nervous system is comprised of neurons organised into networks that form neural circuits and pathways of varying complexity through which information is continuously transmitted. With support from glial cells, communication throughout the nervous system is an extremely fast and efficient process.

A neuron may have from one to 20 dendrites, each dendrite may have from one to many branches, and the total numbers of spines on the branches may be in the hundreds or thousands. This means that a single neuron can have many thousands of connections to other neurons through its dendritic branches and spines. Each spine may have multiple kinds of receptors to gather different types of chemical messages from other neurons. Consequently, a single neuron can have the capability to receive, virtually simultaneously, many and various kinds of information from dozens, hundreds, or even thousands of other neurons. When the dendrites receive information from other neurons, they pass it on to the neuron's soma (cell body) where it is integrated. The soma may collect and integrate information from thousands of other neurons. Once the incoming information from other neurons has been integrated in the soma, it is transmitted along the axon.

An axon is a single, tubelike, extension that transmits neural information to other neurons (or cells in muscles and glands). Most neurons have only one axon but many axons have branches that allow a message to be sent to multiple cells. Axons vary in length; for example, some axons extend over a metre from your spine to your big toe, others are as small as the width of a single hair. Nerves are actually cable-like bundles of multiple axons (see figure 2.16).
The axons of many, though not all, neurons are myelinated. **Myelin** is a white, fatty substance (made up of certain types of glial cells) that surrounds and insulates the axon, much like the plastic tubing around copper wires in an electrical cord. Without the coating, called the **myelin sheath**, interference from the activity of other nearby axons may occur. In addition, the myelin sheath allows for the rapid movement of the message along the axon without being interrupted or distorted. Messages travel much faster through neurons wrapped in myelin than unmyelinated neurons.

The myelin sheath is not continuous along the full length of the axon. It occurs in segments that are separated by small unmyelinated gaps (called **nodes of Ranvier**). The neural message jumps from node to node and this is believed to speed up transmission.

The importance of the myelin sheath is evident in people with multiple sclerosis. In this disease, the body’s immune system attacks the myelin or the glial cells that produce and maintain it. Recurrent attacks by antibodies break down the myelin (called demyelination) and the axons themselves may also be damaged. The cause is still unknown. It may be due to something which causes the immune system to react in this way, or because there are issues with the myelin and that the immune system attempts to clean up the damage. Demyelination ultimately creates areas of scarring (‘sclerosis’) which disrupt the transmission of neural messages within the nervous system. This can result in impairment of motor, sensory and cognitive functions to a greater or lesser extent, depending on which part of the nervous system is damaged and the severity of the damage (MS Australia, 2016).

**FIGURE 2.16** Incoming neural messages are received by the dendrites and transmitted to the soma (cell body) where the information is integrated. Outgoing information is transmitted from the soma to the axon terminals and on to dendrites of other neurons. Within the neuron, the message is in an electrical form called an action potential (or neural impulse).

**Myelin**

**FIGURE 2.17** Myelin surrounds and insulates the axon, as well as allowing for the rapid movement of the message along the axon. This photo, taken using a coloured scanning electron micrograph (SEM), shows myelinated nerve fibres.
Axon terminals
There are small branches at the end of an axon called axon collaterals. At the end of the collaterals are **axon terminals**. Each axon terminal has a small knob-like swelling at its tip called a **terminal button** (sometimes called a **synaptic vesicle**, **synaptic knob** or **synaptic button**). The terminal button is a small structure like a sac that stores and secretes **neurotransmitter** that is manufactured by the neuron and carries its chemical message to other neurons or cells.

Information always travels in one direction through a neuron. It is received by dendrites, passes through the soma and exits from the axon. The neural message to be sent by a neuron originates at the soma. It is in the form of an electrical signal. When it reaches the axon terminals, it stimulates the release of neurotransmitter from the terminal buttons. The neurotransmitter will carry the message to the next neuron in a chemical form. Although each neuron has only one axon, the collaterals and axon terminals allow its message to be sent to many other neurons simultaneously.

**Box 2.3**

**Three types of neurons**
Neurons can be classified in terms of their specific function and the direction that they send information. The three classes are sensory neurons, motor neurons and interneurons.

(a) (b) (c)

![Diagram](image)

**Figure 2.18** The term 'nerve' is commonly used for a neural pathway or circuit outside the CNS and 'tract' for a pathway within the CNS.

**Figure 2.19** (a) Sensory neuron receives and carries sensory information from both the external and internal environments and transmits to the CNS. Also called an afferent neuron or affector. (b) Motor neuron carries messages from the CNS to cells in skeletal muscles, organs and glands to stimulate activity. Also called an efferent neuron or effector or motoneuron. (c) Interneuron sends messages between sensory and motor neurons within the CNS, relaying information from one to the other (because sensory and motor neurons rarely ever connect directly). Also called a connecting or association neuron.

(continued)
Figure 2.20 shows the interaction between the three types of neurons to enable a spinal reflex.

**LEARNING ACTIVITY 2.12**

**Review questions**

1. What is a neuron?
2. Explain the meaning of the statement ‘Neurons are the primary functional units of the entire nervous system’.
3. In what way are the structure and functions of a dendrite different from those of axon terminals?
4. (a) Label the following diagram of a neuron. A copy of the diagram can be accessed in your eBook. It may also be labelled within, then printed from your eBook.
   (b) Draw each of the following on the diagram:
      i. dendrites of an adjacent neuron
      ii. axon of an adjacent neuron
5. Match the part of the neuron in the list with its role in the transmission of a neural message.
   a. myelin
   b. terminal button
   c. dendrite
   d. axon
   e. axon terminal
   f. dendritic spine
   g. axon collateral
   h. soma
   i. integrates information received by dendrites
   j. receives information from another neuron
   k. provides a specific receptor site for neural information
   l. transmits neural information to another neuron
   m. white, fatty substance surrounding an axon that insulates the neuron and increases the speed of neural communication
   n. small branch at the end of an axon
   o. extension of an axon collateral
   p. stores and secretes neurotransmitter

The correct answers can be found at the end of the text.
role of neurotransmitters
When neurons communicate with one another, they do so by sending neurotransmitter across the tiny space between the terminal buttons of one neuron, which release the neurotransmitter, and the dendrites of another, which receive the neurotransmitter. This tiny space is called the synaptic gap (or synaptic cleft). The synaptic gap is about 500 times thinner than a strand of your hair. It is one component of the synapse. The synapse is the site where communication occurs between adjacent neurons. The other two components of the synapse are the terminal buttons of the presynaptic ('sending') neuron and the dendrites of the postsynaptic ('receiving') neuron.

Neurotransmitter is a chemical substance produced by a neuron that carries a message to other neurons or cells in muscles, organs or other tissue. When carrying a message to another neuron, neurotransmitter works by attaching itself ('binding') to receptor sites of postsynaptic neurons that are specialised to receive that specific neurotransmitter. Therefore, receptors on dendrites play a vital role in the communication process.

Neurotransmitter that does not bind to receptors in the postsynaptic neuron is absorbed back into the terminal buttons by the presynaptic neuron in a process called reuptake. Once the postsynaptic neuron has received the neurotransmitter, any additional neurotransmitter that is left in the synapse will also be reabsorbed by the presynaptic neuron. Many medications work by affecting the process of reuptake in order to increase or reduce the availability of a particular neurotransmitter(s) in the brain.

Generally, a specific type of neurotransmitter will have either of two effects. Some neurotransmitters have an excitatory effect and consequently stimulate or activate postsynaptic neurons to perform their functions. Other neurotransmitters have an inhibitory effect and block or prevent postsynaptic neurons from firing.

Some neurotransmitters also occur as hormones. For example, noradrenaline (also called norepinephrine) is a neurotransmitter and a hormone. It is secreted as a hormone by the adrenal glands into the blood, and as a neurotransmitter from neurons.

Glutamate and GABA are the most common neurotransmitters in the CNS. Neurons in virtually every brain area use these two chemical messengers to communicate with each other.

Glutamate (Glu) is the primary excitatory neurotransmitter in the CNS. This means that glutamate enhances information transmission by making postsynaptic neurons more likely to fire. It is the second most abundant neurotransmitter in the brain and involved in most aspects of normal brain function, including perception, learning, memory, thinking and movement. The release of glutamate is associated with enhanced learning and memory.

**Figure 2.22** Neurons do not link together like a chain. The branches of an axon almost touch the dendrites of an adjacent neuron, leaving a tiny space called a synaptic gap.

**Figure 2.23** When the neural message reaches the axon terminal, neurotransmitter is released from the terminal buttons, which carry the message across the synaptic gap to the receiving neuron.
Despite its importance, too much or too little glutamate can actually be harmful to neurons and brain functioning as a whole. For example, abnormally high concentrations of glutamate can lead to overexcitation of receiving neurons. This overexcitation can lead to effects that can cause neuronal damage and/or death by overstimulating them.

**Gamma-amino butyric acid (GABA)** is the primary inhibitory neurotransmitter in the CNS. It works throughout the brain to make postsynaptic (‘receiving’) neurons less likely to fire (i.e. it ‘inhibits’ firing). One of its roles is to fine-tune neurotransmission in the brain and maintain neurotransmission at an optimal, or ‘best possible’, level.

Without the inhibitory effect of GABA, activation of postsynaptic neurons might get out of control. Their uncontrolled activation could spread throughout the brain, causing seizures similar to those of epilepsy and other problems. Anxiety symptoms such as those experienced by people with phobias have been connected to a low level of GABA in the brain, thereby impacting on the regulation of neuronal transmission in the brain. The link between anxiety and a dysfunctional GABA system is examined in chapter 13 on page 000.

In sum, the inhibitory action of GABA counterbalances the excitatory activity of glutamate and vice versa. Consequently, GABA and glutamate have important roles in regulating central nervous system arousal.

**Neurotransmission as a lock-and-key process**

Each type of neurotransmitter has a chemically distinct shape. When released by the presynaptic neuron, neurotransmitter searches for the correctly shaped receptor site on the dendrites of the postsynaptic neurons. Like a key in a lock or a piece of a jigsaw puzzle, a neurotransmitter’s shape must precisely match the shape of the receptor site on the postsynaptic neuron’s dendrites in order to bind (attach) to its receptors. The binding ‘unlocks’ the postsynaptic neuron’s response so that the neurotransmitter causes changes to the neuron, resulting in an excitatory or inhibitory effect. This is why chemical neurotransmission is often referred to as a lock-and-key process. The neurotransmitter is the key and the receptor site is the lock but only for a specific key. This is similar to the lock for the front door of a house.

A postsynaptic neuron can have many different shaped receptor sites on its dendrites and may therefore be able to receive several different neurotransmitters. The effects of a neurotransmitter are not entirely caused by the chemical. Its effects are also due to the receptor to which the neurotransmitter binds. The same neurotransmitter can be excitatory or inhibitory, depending on the properties of the receptor and on the receptor’s location in the brain.

The number of neurotransmitters that a neuron can manufacture varies. Some neurons manufacture only one type of neurotransmitter, whereas other neurons manufacture two or more. Although estimates vary depending on the source, researchers have identified over 60 different neurotransmitters.
While communication between one neuron and another is usually a chemical process involving neurotransmitters, communication between neurons also occurs in other ways. In some instances, communication between neurons is electrical; for example, when axons transmit messages directly to other axons or directly to the cell body of other neurons and when dendrites of one neuron communicate directly with the dendrites of other neurons.

**Figure 2.26** Acetylcholine (ACh) is the neurotransmitter that regulates the contraction of the muscles, including those required for breathing. In South America, indigenous Indian hunters dip their arrows and blowgun darts into a poison called curare, which blocks that action of ACh, paralysing their prey.

### LEARNING ACTIVITY 2.13

**Review questions**

1. (a) What is neurotransmitter? (b) What role does neurotransmitter play in neural communication at a synapse?

2. (a) What is a synapse? (b) Name the three components of a synapse and outline their roles in communication between neurons.

3. Mark each of the following on the following diagram:
   - synaptic gap
   - neurotransmitter
   - synapse
   - terminal button
   - postsynaptic neuron
   - presynaptic neuron
   - receptor site
   - postsynaptic neuron

4. Distinguish between excitatory and inhibitory effects of a neurotransmitter with reference to glutamate and GABA.

5. Outline the chemical neurotransmission process with reference to the lock and key model.

6. Match each neurotransmission term with its correct description:
   - presynaptic neuron
   - synaptic gap (cleft)
   - reuptake
   - binding
   - receptor site
   - excitatory effect
   - glutamate
   - synaptic
   - neurotransmitter
   - terminal button
   - inhibitory effect
   - gamma-amino butyric acid (GABA)
   - tiny space between the terminal buttons of a sending neuron and the dendrites of receiving neuron
   - receiving neuron
   - when terminal buttons ‘take back’ neurotransmitter
   - where neurotransmitter is received
   - an excitatory neurotransmitter in the CNS
   - sending neuron
   - neural message in a chemical form
   - point of communication occurs between adjacent neurons
   - where neurotransmitter is released
   - block or prevent a postsynaptic neuron from firing
   - stimulate or activate a postsynaptic neuron
   - attachment of neurotransmitter to a receptor site
   - an inhibitory neurotransmitter in the CNS
HOW INTERFERENCE TO NEUROTRANSMITTER FUNCTION CAN AFFECT NERVOUS SYSTEM FUNCTIONING

The vital role played by neurotransmitters in communication between neurons makes it clear that we are crucially dependent on them. More specifically, our ability to do virtually anything depends on the neurotransmitters in our nervous system functioning as they should, as well as having them in the biologically correct amounts. For example, there is compelling research evidence that too little or too much of a specific neurotransmitter can have a significant impact on how we think, feel or behave because of its effect on nervous system functioning. Abnormal levels of specific neurotransmitters have been linked to various problems with mental processes and behaviour. This is illustrated by the role of dopamine in Parkinson’s disease.

Parkinson’s disease

Parkinson’s disease is a CNS neurodegenerative disorder characterised by both motor and non-motor symptoms. Motor symptoms result from the degeneration and loss of neurons in the substantia nigra. The substantia nigra, located in the midbrain, has a role in the control of voluntary muscle movements so they can be executed in a smooth and coordinated manner, such as the normal sequence of movements required for balance, walking, talking and writing.

Neurons in the substantia nigra produce the neurotransmitter called dopamine, so when the substantia nigra is diseased or damaged, the amount of dopamine available for motor activity reduces as neurons gradually die. The level of dopamine continues to fall over many years.

Dopamine from the substantia nigra carries messages on how to control body movements, in the first instance to the nearby basal ganglia, and from there to motor cortex in the frontal lobes (Parkinson’s Australia, 2016a).

If there are fewer neurons in the substantia nigra, less dopamine will be produced. This means that the brain structures such as the basal ganglia and motor cortex that are involved in planning, coordinating and initiating voluntary movements receive slower, fewer and/or irregular dopamine messages about motor activity.

Ultimately, the primary motor cortex which executes voluntary movements receives inadequate information due to insufficient and impaired activation by dopamine. Movement commands are disrupted because essential messages about how and when to move have gaps or have not been received. The decrease in dopamine does not account for all symptoms experienced with the disorder (Parkinson’s Australia, 2016b).

Motor symptoms begin to appear only after extensive neuronal death. As we age, we all experience a loss of neurons in the substantia nigra, but only after we have lost about 60% of them would we start to show motor symptoms like those of Parkinson’s disease. Although Parkinson’s disease is progressive, the rate at which its symptoms worsen is variable, and only rarely is progression so rapid that a person becomes disabled within 5 years (Kolb & Whishaw, 2014; National Institute of Neurological Disorders and Stroke [NINDS], 2015).

Although Parkinson’s disease is linked to the degeneration of dopamine-producing neurons, it is not known what actually causes these neurons to become diseased or damaged. Parkinson’s disease is a complex condition and currently the cause is unknown.

**FIGURE 2.27**

(a) Parkinson’s disease is a CNS neurological disorder primarily involving degeneration of dopamine producing neurons in the substantia nigra. These neurons are partly responsible for starting a circuit of messages that coordinate voluntary movement. b. This cross-section of the brain shows the substantia nigra, basal ganglia and motor cortex areas which interact with each other and other structures in planning, coordinating and initiating voluntary movements. The dopamine motor activity pathway from the substantia nigra is shown in red.
In a weakened substantia nigra, dopamine-producing neurons have degenerated, eventually contributing to symptoms of Parkinson's disease. Therefore, it is described as idiopathic, which means 'having no known cause'. Parkinson's disease is not considered to be genetic though there is a family history of the disorder in about 15% of cases. The only real risk factor seems to be age (Parkinson's Australia, 2016b).

**Symptoms of Parkinson's disease**

The symptoms of Parkinson's disease develop slowly and gradually progress over years. They tend to vary greatly between individuals diagnosed with the disorder and no two people will be affected in the same way. In addition, both motor and non-motor symptoms also tend to vary in severity from day to day and at different times throughout the day.

According to Parkinson's Australia (2016b), four key symptoms are used for diagnostic purposes. These are all motor symptoms.

**Tremor** involving continuous, involuntary shaking (trembling) of the body is the best-known symptom, but is not necessarily experienced in all cases. Some 30% of people with the disease will not experience tremor. Most often, tremors are 'resting tremors' and occur when the affected limb is not in use. These tremors tend to be regular and rhythmic, occurring at the rate of about 4–6 times per second. 'Restless legs' is also common. This is when the person's legs appear to move or feel as if they are moving constantly.

**Muscle rigidity**, or 'stiff muscles', whereby the muscles seem unable to relax and are tight, even when at rest, is another key symptom. Individuals report feeling that their muscles will not do what they want them to do. They may have difficulty performing automatic movements, such as swinging their arms when walking or rolling over in bed. They may feel their muscles are so tight that they have frozen and won't actually move.

Rigidity can also lead to lack of facial expression through loss of facial muscle tone. Muscle rigidity first occurs on one side of the body, then eventually progresses to both sides. Over time, muscle rigidity can lead to the characteristic stooped or 'forward bent' posture apparent in many people with the disorder.

**Slowness of voluntary movement** (called bradykinesia), particularly when initiating and executing movement and in performing repetitive movements, presents in a variety of ways, including difficulty starting new movements or stopping an ongoing movement. There is a decrease in fine motor coordination required for 'delicate' work with the hands, such as when doing up buttons, putting on make-up, shaving and hand writing.

Bradykinesia also affects the more critical aspects of daily living, such as walking, talking, chewing, swallowing and speaking, and also contributes to a lack of facial expression. Initially bradykinesia may be misinterpreted as slowing due to ageing; however, it is out of proportion to normal ageing.

**Postural instability, balance problems and gait disturbances** tend to occur later in the course of the disorder. Inability to maintain a steady, upright posture or to take a corrective action to prevent a fall often results in just that — falling. Gait disturbance is apparent in the short, shuffling steps taken by individuals and reduced arm swing. In advanced Parkinson's disease, there may be episodes of freezing in which the feet appear to be glued to the floor.

Non-motor symptoms may include a decrease or loss of sense of smell (called anosmia), sweating and increased sensitivity to temperatures, fatigue which is not relieved by resting, and mental health problems such as confusion, panic attacks, anxiety disorder and depression. Problems with cognitive function such as slowness of thinking, impaired planning and decision making and memory loss may occur in up to 40–50% of people with Parkinson's disease, especially late in the disease, especially late in the disease and in older people (Golbe, Mark & Sage, 2014; Parkinson's Australia (2016b)).

Due to the very slow onset of Parkinson's disease, it can often take a long time for people to realise their reduced ability to control movement and other motor symptoms. For some, a slight tremor of the hand when it is relaxed and not in use will be the first sign that something is wrong. For others, difficulty with walking, or falling due to disturbed balance control, may be the first sign of the disorder.
There is currently no known cure for Parkinson's disease, but motor symptoms such as tremor, muscle rigidity and slowness of movement may be relieved by medications that restore the deficiency of dopamine by increasing the level of dopamine in the brain. Two types of medications can be used — those that can be converted into dopamine by neurons and those that mimic the role of dopamine and are able to effectively stimulate reception of dopamine by neurons within crucial motor areas by causing neurons to react as they would to dopamine. Not all symptoms respond equally to the medications (NINDS, 2015) (see box 2.4).

There is research evidence that midbrain dopamine neurons release not only dopamine but also another neurotransmitter called GABA, which has the effect of inhibiting or reducing neuronal activity (see pages 000–000). It is believed that overlooking the reduced level of GABA and adopting a single-focus approach of targeting only dopamine for treatment may explain why initial improvements in people with Parkinson's disease associated with the use of dopamine medications tend not to persist and eventually disappear (Tritsch, Ding & Sabatini, 2012).

**Tremor** is also related to a low level of the neurotransmitter acetylcholine, which contributes to voluntary movement (see figure 2.26). For this reason, tremor is often the least responsive symptom to dopamine replacement therapy. Bradykinesia and rigidity respond best to levodopa. Problems with balance may not be alleviated at all. Other medications, such as bromocriptine, pramipexole, and ropinirole, mimic the role of dopamine in the brain, causing the neurons to react as they would to dopamine (NINDS, 2015; Parkinson's Australia (2016b).

It is relatively common for people to require high doses of medication and therefore experience side effects as the disorder progresses and natural dopamine production is reduced. In many cases, medication has a maximum benefit for a period of 5–10 years. Neuron degeneration continues relentlessly and eventually too few dopamine-containing neurons remain in the substantia nigra, and levodopa stops being effective. Some non-motor symptoms may actually be aggravated by dopamine boosting medications and many people with Parkinson's disease report that some of the side effects are as disabling as the disorder itself (Parkinson's Victoria, 2016).

In some cases, the deep brain stimulation (DBS) procedure may be a treatment option. This is a surgical procedure to enable electrical stimulation of the brain. The patient is conscious during the surgery so that responses to stimulation can be assessed. Very fine wires with electrodes at their tips are implanted in the brain, usually in or near the basal ganglia. These are connected to a pulse generator (a device like a heart pacemaker), which is placed under the skin around the chest or
stomach area. When the device is switched on, the electrodes stimulate the targeted area with tiny amounts of electric current, thereby blocking the abnormal neural messages (electrical signals) that cause motor symptoms. As a result, some of the motor symptoms may be alleviated and the individual may be able to reduce the amount of medication previously required. However, not all Parkinson’s motor symptoms will necessarily respond to the electrical stimulation. At present, the procedure is used only for individuals with debilitating motor symptoms that cannot be adequately controlled with medications. The treatment has been found to improve motor symptoms (particularly tremor) and reduce the need for levodopa, but it carries the risk of side effects such as impulsive behaviour and difficulties with decision making. In addition, some people experience increased depression and anxiety (Frank, et. al., 2007; Parkinson’s Australia (2016c)).

(a)

(b)

**Figure 2.30** (a) One of the most commonly used and effective medications is L-dopa, made from levodopa, a chemical that is converted to dopamine by neurons. (b) Deep brain stimulation may also be a treatment option to reduce the need for medications or when they are no longer effective, especially in the later stages of the disease when motor symptoms are very debilitating. It is a surgical procedure during which the patient is conscious so that responses to stimulation can be assessed.

**BOX 2.5**

**Neuroimaging techniques used for brain research**

A major problem confronting early researchers interested in studying the brain was the lack of technology to directly observe a normal intact human brain in action. Consequently, early researchers, most of whom were medical doctors, often studied the brains of dead animals and those of dead people who had donated their bodies to medical science.

Living people and animals were also studied. Studies with animals often included experiments. Many animal experiments involved the destruction or surgical removal of a specific brain structure or area to study the effects on behaviour. Studies with people were often case studies of individuals who had experienced brain damage due to an accident, crime or disease.

Although early research provided useful information about the brain, this was mainly limited to the **structure** of the brain. Relatively little was known about the **function** of the brain; that is, how the brain actually ‘works’ when we are thinking, feeling or behaving. The development of new brain recording and imaging technologies during the latter half of the 20th century helped advance understanding of the brain in significant ways.

**Neuroimaging**, commonly called ‘brain scanning’, can capture detailed images of the living intact brain as people engage in different mental processes or make behavioural responses. Importantly, neuroimaging techniques are ‘non-invasive’. This means that researchers can use them without entering the brain. Therefore, the risk of harm to participants is minimal, if not negligible. Table 2.2 summarises some of the better known neuroimaging techniques used for brain research conducted by psychologists.

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### TABLE 2.2 Examples of neuroimaging techniques for brain research

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<thead>
<tr>
<th>Neuroimaging technique</th>
<th>Description</th>
<th>Research applications</th>
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| **Computed tomography (CT) or Computed axial tomography (CAT)** | Produces computer-enhanced cross-sectional images of the brain from X-rays taken at different angles | • Useful diagnostic tool that shows brain structures or areas affected by disease or injury  
• Images are much more detailed than standard X-rays  
• Cannot reveal brain function |
| **Magnetic resonance imaging (MRI)** | Harmless magnetic fields and radio waves are used to produce computer-enhanced colour images in 2D or 3D | • Useful diagnostic tool that shows brain structure more clearly and in greater detail than CT  
• Cannot reveal brain function |
| **Functional magnetic resonance imaging (fMRI)** | An enhanced version of MRI that detects brain activity during a given task through changes in oxygen levels in blood flowing through the brain. | • Shows brain structure and brain activity as it happens in highly detailed images  
• Like PET but more precise and detailed images of brain activity |
### Neuroimaging technique

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| Positron emission tomography (PET) | Radioactive tracer is injected into the bloodstream (or taken orally) and acts like glucose, which is used when the brain is active. When it reaches the brain, the amount used during a given task is recorded. Computer-generated colour-coded images showing areas of high and low activity are produced. | • Widely used for experimental research on brain function  
• Shows areas of brain activity (and inactivity) during a wide variety of tasks such as selective attention, daydreaming, limb movement, planning, problem solving, speech, learning and remembering |

**FIGURE 2.31d** PET scan of brain activity during mathematical problem solving. At left is the brain of a person reciting multiplication tables, while at right the person is performing repeated subtractions. Active brain areas are shown in orange.

### Learning Activity 2.14

**Review questions**

1. Explain what Parkinson’s disease is with reference to three key motor symptoms and examples of non-motor symptoms.
2. Why can Parkinson’s disease be described as a neurological disorder? a neurodegenerative disorder?
3. (a) In which brain structure of people with Parkinson’s disease is dopamine found to be at a depleted level?  
   (b) Where is this structure located?
4. (a) What two changes at the neurotransmitter level might be targeted by medications designed to treat Parkinson’s disease motor symptoms?  
   (b) What change to dopamine action is targeted by deep brain stimulation?
5. Explain how the psychological experience of motor symptoms can worsen or contribute to the development of non-motor symptoms.

### Learning Activity 2.15

**Reflection**

Parkinson’s disease is commonly described as a disorder that impairs the *control* of voluntary movements rather than the *production* of voluntary movements (as in paralysis). Comment on the accuracy of this description with reference to Parkinson’s disease motor symptoms.
CHAPTER SUMMARY

NERVOUS SYSTEM FUNCTIONING

- Roles of different divisions
  - Central nervous system
  - The brain
  - The spinal cord
  - Peripheral nervous system
  - Somatic nervous system
  - The autonomic nervous system
  - Divisions of the ANS

- Conscious and unconscious responses to sensory stimuli
  - The spinal reflex
  - Dendrites
  - Axon
  - Myelin
  - Axon terminals

- Role of the neuron
  - Neurotransmission as a lock-and-key process
  - Parkinson's disease
  - Symptoms of Parkinson's disease

- Role of neurotransmitters
  - Parkinson's disease

- How interference to neurotransmitter function can affect nervous system functioning
  - Parkinson's disease

SOMATIC NERVOUS SYSTEM

SOMATIC NERVOUS SYSTEM

- The sympathetic nervous system
- The parasympathetic nervous system

SUMMARY

- Roles of different divisions
- Conscious and unconscious responses to sensory stimuli
- Role of the neuron
- How interference to neurotransmitter function can affect nervous system functioning

NERVOUS SYSTEM

NERVOUS SYSTEM

- The brain
- The spinal cord
- Peripheral nervous system
- Somatic nervous system
- The autonomic nervous system
- Divisions of the ANS

THE BRAIN

THE SPINAL CORD

THE SOMATIC NERVOUS SYSTEM

THE AUTONOMIC NERVOUS SYSTEM

DIVISIONS OF THE ANS

UNIT 3 How does experience affect behaviour and mental processes?
KEY TERMS
acid (GABA) p. 000
autonomic nervous system (ANS) p. 000
axon p. 000
axon terminals p. 000
brain p. 000
central nervous system (CNS) p. 000
conscious response p. 000
dendrite p. 000
Gamma-amino butyric acid (GABA) p. 000
Glutamate (Glu) p. 000
myelin p. 000
neuron p. 000
neurotransmitter p. 000
parasympathetic nervous system p. 000
Parkinson’s disease p. 000
peripheral nervous system (PNS) p. 000
somatic nervous system (SNS) p. 000
spinal cord p. 000
spinal reflex p. 000
sympathetic nervous system p. 000
synapse p. 000
synaptic gap p. 000
unconscious response p. 000

LEARNING CHECKLIST
Complete the self-assessment checklist below, using ticks and crosses to indicate your understanding of this chapter’s key knowledge (a) before and (b) after you attempt the chapter test. Use the ‘Comments’ column to add notes about your understanding.

<table>
<thead>
<tr>
<th>Key knowledge I need to know about mental health</th>
<th>Self-assessment of key knowledge I understand before chapter test</th>
<th>Self-assessment of key knowledge I need to revisit after chapter test</th>
<th>Comments</th>
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CHAPTER TEST

SECTION A — Multiple-choice questions

Choose the response that is correct or that best answers the question.
A correct answer scores 1, an incorrect answer scores 0.
Marks will not be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.

Question 1
A major function of the spinal cord is to
A. protect the spinal column.
B. initiate voluntary muscle movements.
C. connect the brain and central nervous system.
D. connect the brain and peripheral nervous system.

Question 2
You are working quietly in the library when a friend sneaks up from behind and scares you, making your heart race. At this time, your ____ nervous system would be dominant.
A. parasympathetic
B. sympathetic
C. somatic
D. central

Question 3
Sensory pathways carry information to the ____ and motor pathways carry information from the ____.
A. somatic nervous system; peripheral nervous system
B. central nervous system; somatic nervous system
C. central nervous system; central nervous system
D. peripheral nervous system; peripheral nervous system

Question 4
A mosquito lands on your arm. You watch it carefully then move your hand to swat it. Your sensation and response are due to ____ activity.
A. spinal reflex
B. autonomic nervous system
C. somatic nervous system
D. parasympathetic nervous system

Question 5
Parkinson’s disease motor symptoms are associated with
A. an excessive amount of dopamine in motor pathways.
B. loss of dopamine as it travels along motor pathways.
C. overproduction of dopamine in the substantia nigra.
D. a depleted amount of dopamine in the substantia nigra.

Question 6
Sensory information is best described as ____ information.
A. afferent
B. efferent
C. internal
D. external

Question 7
The ____ nervous system automatically restores bodily systems to their normal level of functioning after the need for heightened activity has passed.
A. somatic
B. central
C. sympathetic
D. parasympathetic

Question 8
Jana was diagnosed with paraplegia after a horse riding accident and can no longer walk. She is unable to do so because her ____ nervous system cannot communicate with her ____ nervous system.
A. central; autonomic
B. somatic; central
C. somatic; sympathetic
D. autonomic; sympathetic

Question 9
The autonomic nervous system
A. controls movements of skeletal muscles.
B. initiates movements of skeletal muscles.
C. controls the activities of visceral muscles, organs and glands.
D. controls biofeedback activities and responses.

Question 10
A synapse is
A. a neural connection.
B. a type of neurotransmitter.
C. the place where neurons chemically communicate.
D. the part of the neuron on which small extensions grow.

Question 11
The ____ nervous system initiates skeletal muscle movement, whereas the ____ nervous system regulates the activity of visceral muscles.
A. somatic; autonomic
B. parasympathetic; sympathetic
C. autonomic; somatic
D. peripheral; sympathetic
Question 12
The neurons in the spinal cord are part of the __________ nervous system.
A. central
B. peripheral
C. somatic
D. autonomic

Question 13
The peripheral nervous system transmits information between the ____ and the _____.
A. central nervous system; spinal cord.
B. spinal cord; muscles, organs and glands.
C. sensory receptors, muscles, organs and glands; central nervous system.
D. somatic nervous system; muscles, organs and glands.

Question 14
The two major divisions of the central nervous system are the _____ and the two major divisions of the peripheral nervous system are the _____.
A. somatic and autonomic systems; brain and spinal cord
B. brain and peripheral system; somatic and sympathetic systems
C. somatic system and spinal cord
D. brain and spinal cord; autonomic and somatic systems

Question 15
The substantia nigra is located in the ____ region of the brain.
A. midbrain
B. forebrain
C. hindbrain
D. motor

Question 16
An important role of an axon is to
A. carry a neural message towards a neighbouring neuron.
B. carry a neural message away from a neighbouring neuron.
C. integrate neural information and speed up its transmission.
D. insulate a neuron to speed up its transmission.

SECTION B — Short-answer questions

Answer all questions in the spaces provided. Write using black or blue pen.

Question 1 (6 marks)
Label the following drawing of a neuron.
Include:
(a) axon
(b) axon terminal
(c) myelin
(d) dendrite
(e) an arrow showing the direction of the neural message
(f) a cross (x) showing where neurotransmitter would be secreted.
Question 2 (2 marks)
(a) Give an example of an unconscious response to an internal sensori stimulus. 1 mark

(b) Name the source of the stimulus for (a) 1 mark

Question 3 (2 marks)
The synaptic gap is one component of a synapse. Name the other two components.

Question 4 (3 marks)
Describe the interrelationship of the sympathetic and parasympathetic nervous systems with reference to an example.

Question 5 (2 marks)
Distinguish between the roles of the autonomic and somatic nervous systems.
Question 6 (2 marks)
Explain why someone in a comatose state with severe brain damage may still be able to remain alive for a prolonged period without artificial life support.

Question 7 (5 marks)
(a) List the steps in the spinal reflex sequence of activity that enables a withdrawal response to occur before the brain processes the conscious perception of pain. 3 marks

(b) Explain why a spinal reflex is considered to be an adaptive response with reference to conscious and unconscious responses to sensori stimuli. 2 marks

Question 8 (5 marks)
(a) What is Parkinson’s disease? 1 mark

(b) Explain how two different types of medications for Parkinson’s disease might be designed to work at the neurotransmitter level to reduce key motor symptoms. 4 marks

Question 9 (8 marks)
(a) Within the central nervous system, the neurotransmitter ______________ has an inhibitory effect on neurons and the neurotransmitter ______________ has an excitatory effect. 1 mark

(b) Explain the meaning of excitatory and inhibitory effects of neurotransmitters. 2 marks
(c) What primarily determines whether or not a neurotransmitter will have an excitatory or inhibitory effect? 2 marks

(d) Explain how chemical neurotransmission occurs as a lock-and-key process. 3 marks

Return to the checklist on page xxx and complete your self-assessment of areas of key knowledge where you need to do more work to improve your understanding.

**eBookplus**

The answers to the multiple-choice questions are in the answer section at the back of this book and in eBookPLUS.

The answers to the short-answer questions are in eBookPLUS.

Note that you can also complete Section A of the chapter test online through eBookPLUS and get automatic feedback. int-0000