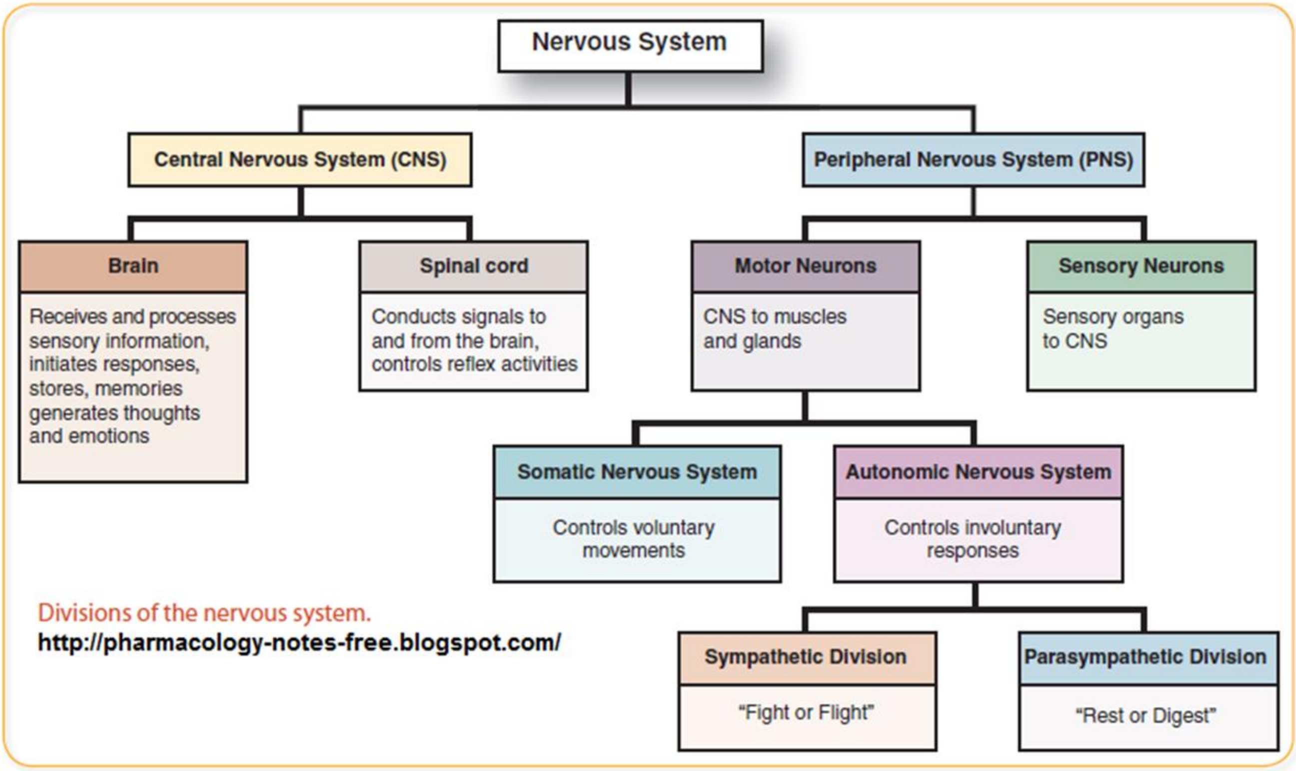
Nervous system functioning

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.



Divisions of the nervous system.
http://pharmacology-notes-free.blogspot.com/

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.

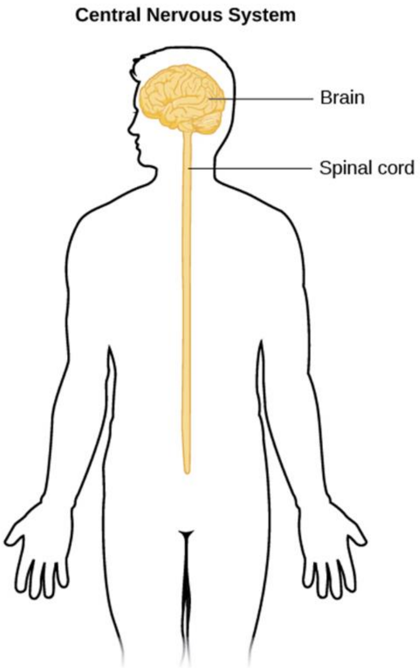
When the sensory information is received at the brain it is processed. This enables perception — interpretation of the sensory information so meaning can be assigned. Processing often involves integrating (combining) incoming information with other information already in the brain. For example, incoming 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.

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 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.



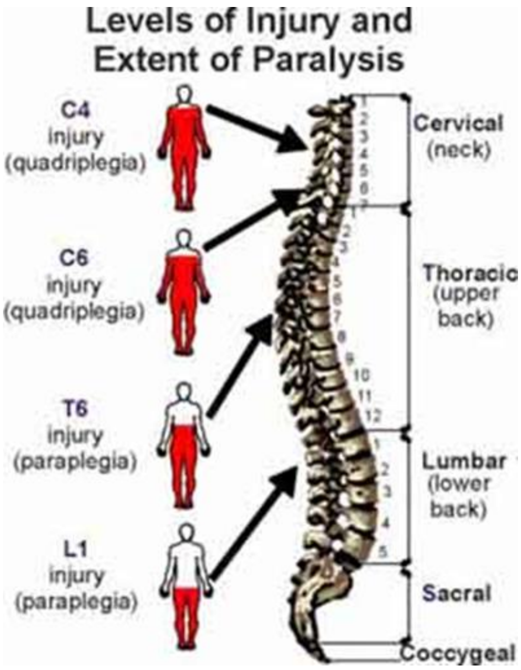
Many brain functions involve the activation of neural pathways that link different brain areas and structures. Neural pathways (also called tracts) comprise one or more circuits of interconnected neurons that form communication networks. Some span short distances and others extend from one side of the 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

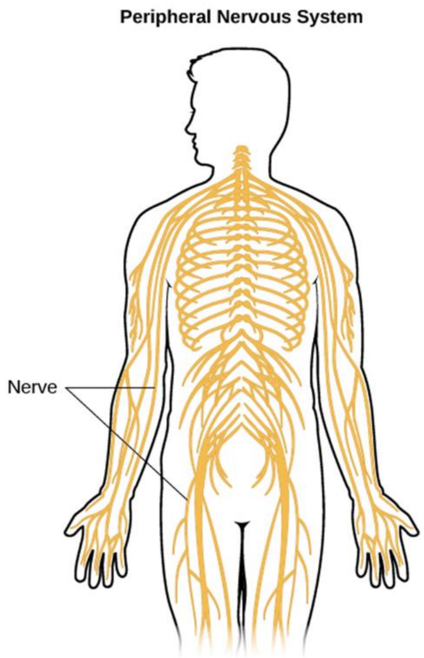
The spinal cord is the long, thin bundle of nerve tissue that extends from the base of the brain to the lower back. The spinal cord links the brain and the parts of the body below the neck. Two major functions of the spinal cord are to:

• 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.



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 it two subdivisions: the somatic nervous system and the autonomic nervous system.

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.

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).

The sensory function of the SNS is demonstrated when someone touches your hand. The SNS sends the sensory signals about touch from the skin to your brain, resulting in the sensation of touch (or pressure on the skin). The motor function of the SNS is demonstrated whenever voluntary actions are performed. For example, when you 'text', talk, chew, shower, surf or dance, your somatic nervous system is active.

Thus, the somatic nervous system is involved in all skeletal muscle activity that enables us to participate in our relationship with the external environment. Its nerves send information to the brain from the body's various sensory receptors. These nerves also enable us to respond to these stimuli by moving through the environment. Although motor pathways carry messages that initiate or stop movement, voluntary movement is controlled through the coordinated actions of both motor and sensory information. For example, when you use a pen to scratch your nose, your brain (primary motor cortex) sends messages via motor neurons to skeletal muscles in your arm, hands and fingers to move in specific ways. Sensory receptors in your skin and muscles send back messages through sensory neurons that help determine how much pressure is needed to hold the pen. However, your somatic nervous system does not make your heart beat faster when you're suddenly threatened or regulate your internal environment. For these reactions, the other

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.

subdivision of the PNS is required—the autonomic 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.

Divisions of the ANS

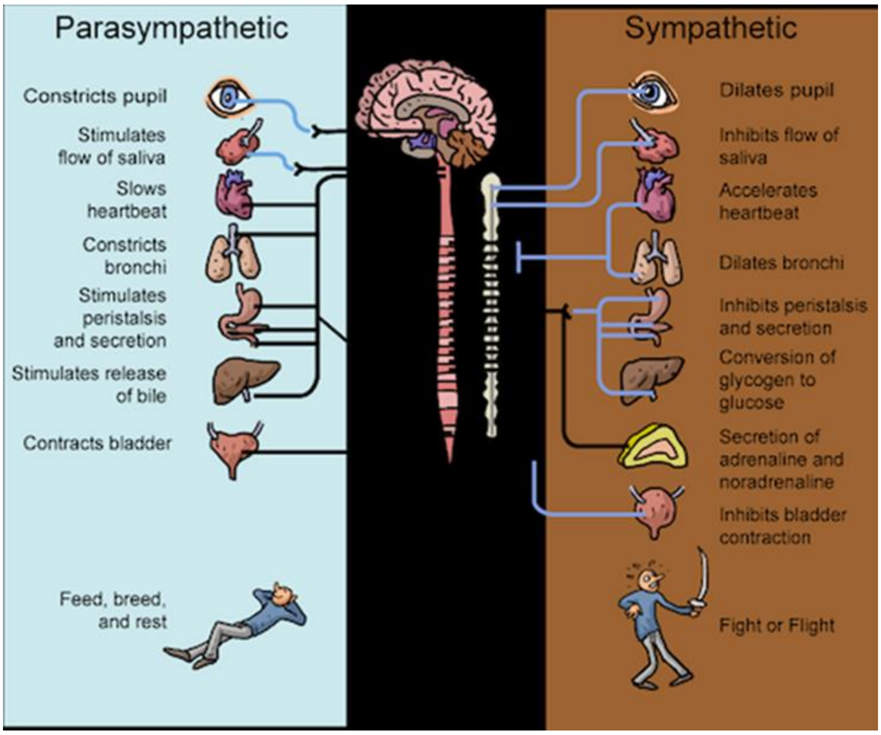
Review questions

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.



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

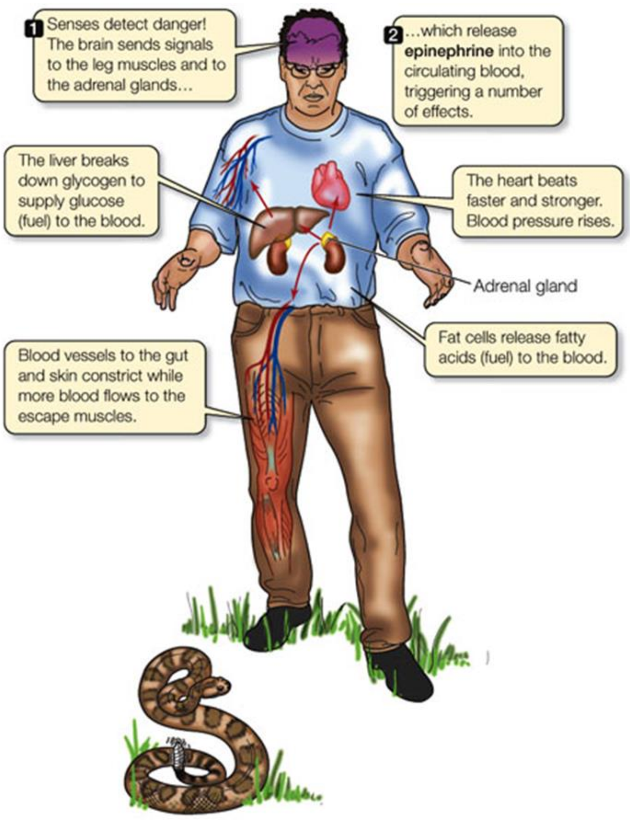
- the sympathetic nervous system, which is responsible for increasing the activity of most visceral muscles, organs and glands in times of vigorous activity, stress or threat
- the parasympathetic nervous system, which is responsible for decreasing the activity of most visceral muscles, organs and glands,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

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 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.

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.

5 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.

6 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.

Adapted from Grivas, J. & Letch, N. (2016) *Psychology VCE Units 3&4*. Richmond: Jacaranda.