5.1 THE CENTRAL NERVOUS SYSTEM

The complete network of all nerve cells in the human body is divided into two systems: the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS is composed of the brain and spinal cord and provides the command and integrating centre of the nervous system. Not only does the CNS contain all the major command centres vital for the maintenance of life, but its higher regions are crucially involved in decision making (that is, detecting sensory events, analyzing this information and deciding how to respond).

The central nervous system (CNS), consisting of brain and spinal cord, is the integrative control centre of the body. In particular, the brain exerts executive control over the peripheral nervous system and endocrine glands, and is the organ of movement, emotion, thought and consciousness. An important prerequisite for understanding how the brain produces behaviour is having a good understanding of its anatomy. This includes knowing where the main brain regions are sited and the ways in which they are connected.

The problem of understanding the structure of brain lies in trying to visualize the shape of brain structures and their pathways. The brain is simply too complex. One simple way to remember the main anatomical terms used to convey direction in the brain is to imagine a fish. Its front end, or head, is anterior (sometimes called rostral), and its tail-fin is posterior (sometimes called caudal). The fish also has a dorsal fin on its upper surface – and one on its underside called the ventral fin. In addition, the fish has lateral fins on its sides – while the term medial would be used to describe parts of the body towards the midline. Two other terms that are useful to know, particularly in regards to neural pathways, are ipsilateral (referring to structures on the same side of the body), and contralateral (referring to structures on the opposite side of the body).

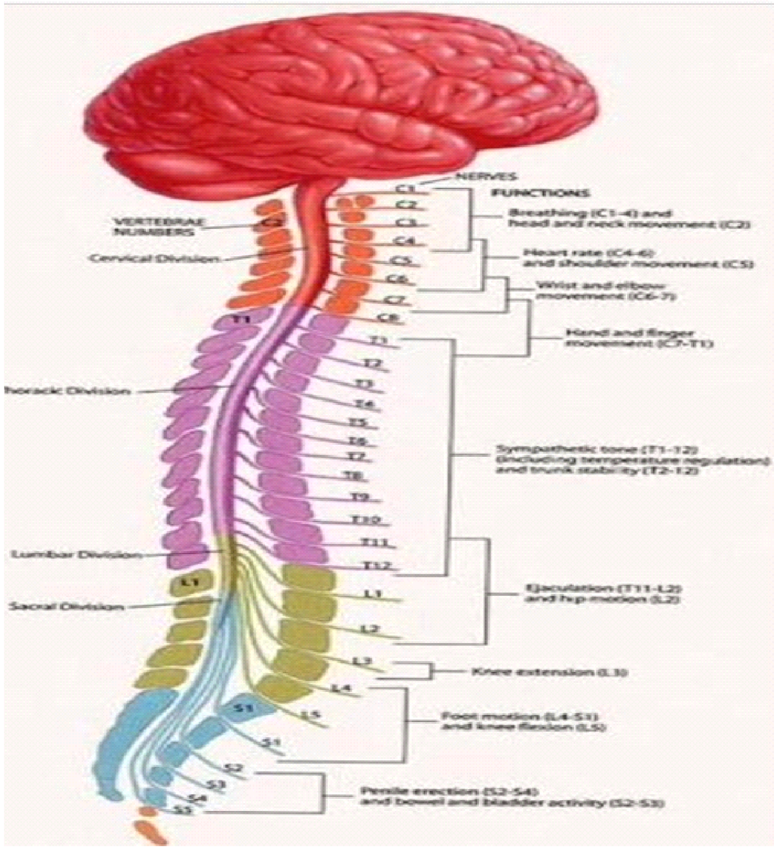

Figure 5.1

5.2 Spinal cord

The spinal cord is an extension of the medulla in the brain, about the size of a large pencil, that forms a cylinder of nervous tissue that runs down the back. The spinal cord in an adult is at about 17 1/4 inches long, is about as wide as thumb, and is just as thin as a straw at the base. It is enclosed and protected by meninges, three layers of membrane just like those surrounding the brain. The spinal nerves come out from the spaces between the bony arches in pairs. They are named for the area of the vertebral column from which they come. These areas include:

- Cervical or neck
- Thoracic or chest

- Lumbar or abdomen
- Sacral or pelvis
- Coccygeal or tailbone

From top to bottom, these segments comprise eight cervical vertebrae, twelve thoracic, five lumbar, five sacral and one coccygeal. The end of the spinal cord is called the cauda equine because it looks like a horse's tail with its cascade of nerves.

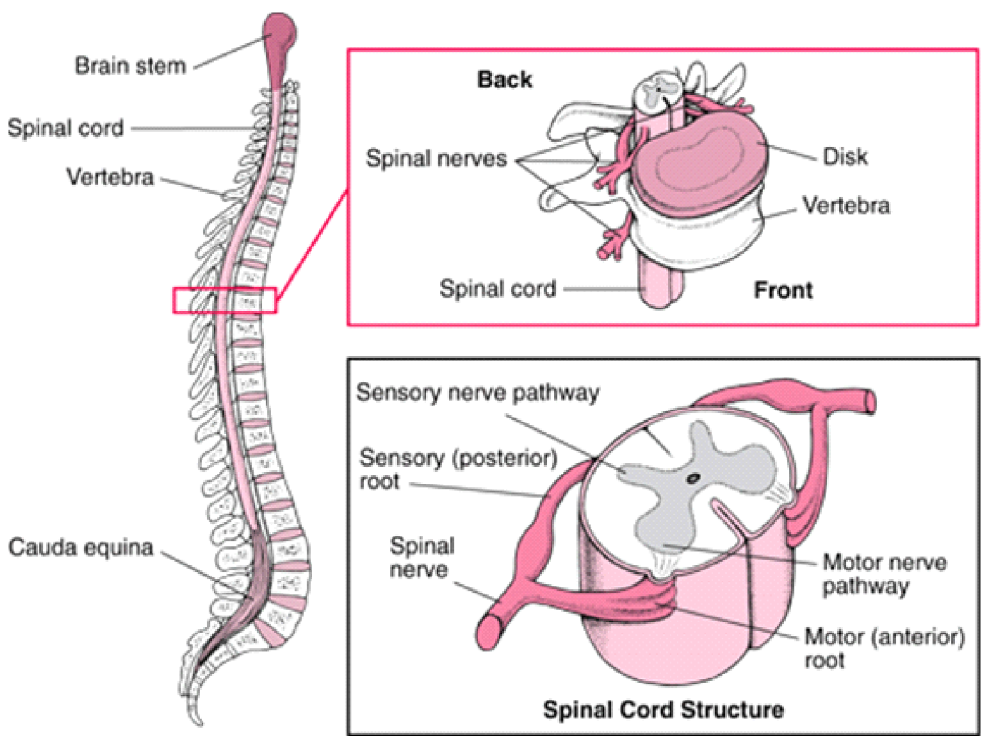

Figure 5.2

The most striking visual feature of the spinal cord is its grey matter (comprising cell bodies) and white matter (comprising myelinated axons). Forming a butterfly shape in the centre of the spinal cord is the grey matter, and this is packed tightly with the cell bodies of various neurons. These include the motor neurons that send their fibres out to innervate the muscles of the body, and a large number of interneurons that are confined to the grey matter.

Interneurons are important because they are located in pathways between sensory fibres going into the spinal cord, and motor fibres going out, which allow complex reflexes to take place. Furthermore, interneurons allow communication to take place between different segments or regions of the spinal cord.

In contrast, the white matter which surrounds the grey material is composed mainly of long myelinated axons that form the ascending and descending pathways of the spinal cord. More precisely, the ascending pathways arise from cell bodies that receive sensory input in the grey matter, and descending axons derive from the brain and pass into the grey matter where they form synapses with motor neurons.

The posterior column conveys touch and pressure information to the thalamus, and the corticospinal tract which passes information all the way from the motor regions of the cerebral cortex. Axons enter or leave the grey matter of spinal cord in spaces between the vertebrae, via spinal nerves which are ganglia containing large numbers of nerve fibres. There are 31 pairs of spinal nerves along the entire length of the spinal cord, and each one serves either the right or left side of the body (Figure 5,3).

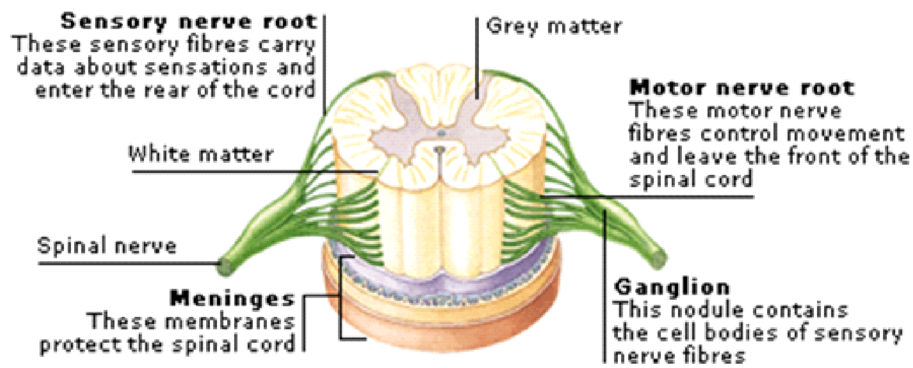

Figure 5.3

5.2.1 Functions

The spinal cord serves many functions: it helps humans maintain an erect posture, and also provides the point of attachment for muscles of the back. However, by far its most important function is to distribute motor neurons to their targets (for examples, muscles and glands), and to convey internal and external sensory information to the brain. Moreover, the spinal cord is also capable of producing certain types of behaviour by itself, including simple spinal reflexes such as the knee jerk response, or more complex patterns of automated rhythmical activity, including the postural components of walking.

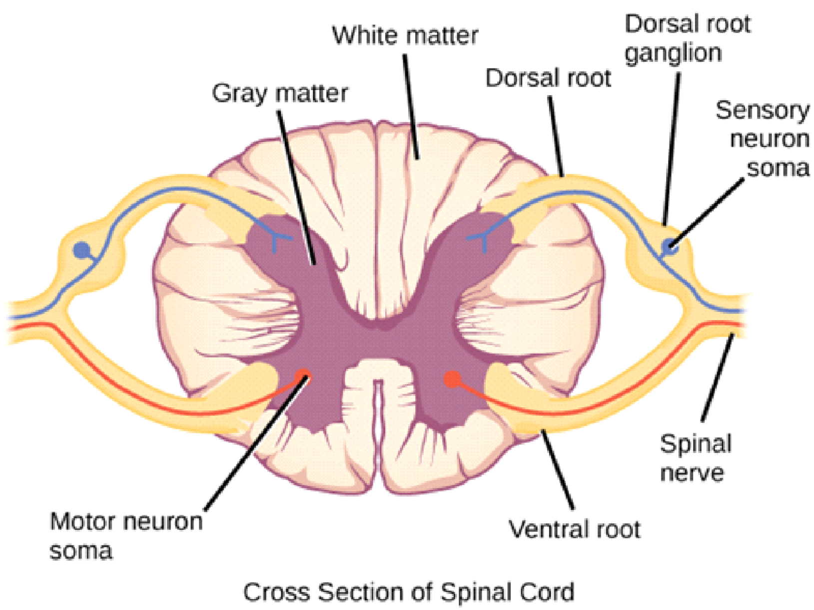

Figure 5.4

Closer examination of these nerves shows that they comprise two branches as they enter or leave the spinal cord (Figure 5.4). The dorsal root of each spinal nerve provides the pathway that relays sensory information into the spinal cord (the cell bodies of these neurons are actually located in the root itself), whereas the ventral root provides the motor pathway that controls the muscles of the body. The spinal cord also contains cerebrospinal fluid which is connected with the brain's ventricles. Samples of this spinal fluid can be a very useful diagnostic tool in determining various brain disorders.

5.3 Structure of Brain

As the spinal cord enters the brain it enlarges and forms the brainstem (Figure 5.5)

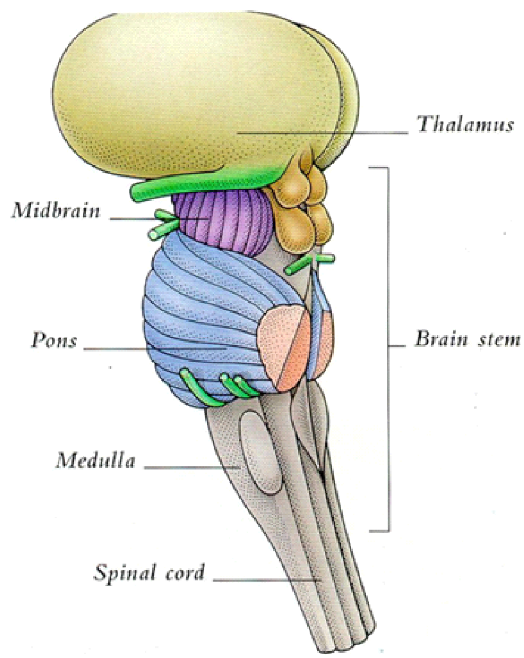

Figure 5.5

5.3.1 Brain stem

The oldest part of the brainstem is the medulla oblongata (‘long marrow’) and this directly controls many functions essential for life, including breathing, heart rate, salivation and vomiting. It also contains a profusion of ascending and descending nerve pathways that connect the spinal cord with the rest of the brain. If the brain is cut above the medulla, basic heart rate and breathing can be maintained, but damage to the medulla itself is inevitably fatal.

The next region is the pons (from the Latin for ‘bridge’) which appears as a significant enlargement of the medulla. This area also contains many nuclei (sometimes called the pontine nuclei) although its increased size is largely due to the many ascending and descending fibre tracts that cross from one side of the brain to the other at this point, including the pyramidal tracts. Two important structures often regarded as pontine nuclei (although they also extend into the midbrain) are the locus coeruleus and dorsal raphe. These are, respectively, the origin of noradrenergic and serotonergic-containing fibres in the forebrain. The pons also includes an area known as the tegmentum, which includes many motor nuclei and secondary sensory cell groups, as well as the beginning of the reticular formation, a tubular net-like mass of grey tissue which is involved in arousal. The pons also serves as the main junction between the cerebellum ('little brain') and the rest of the brain.

The brainstem (medulla and pons) is also the most important part of the brain giving rise to the cranial nerves, which were first discovered by Galen in the first century AD. There are twelve pairs of cranial nerves directly connecting the brain with bodily structures, and eight of these originate or terminate in the brainstem: four from the medulla (hypoglossal, spinal accessory, vagus and glossopharyngeal), and four from the pons (auditory, facial, abducens and trigeminal) (Figure 5.6).

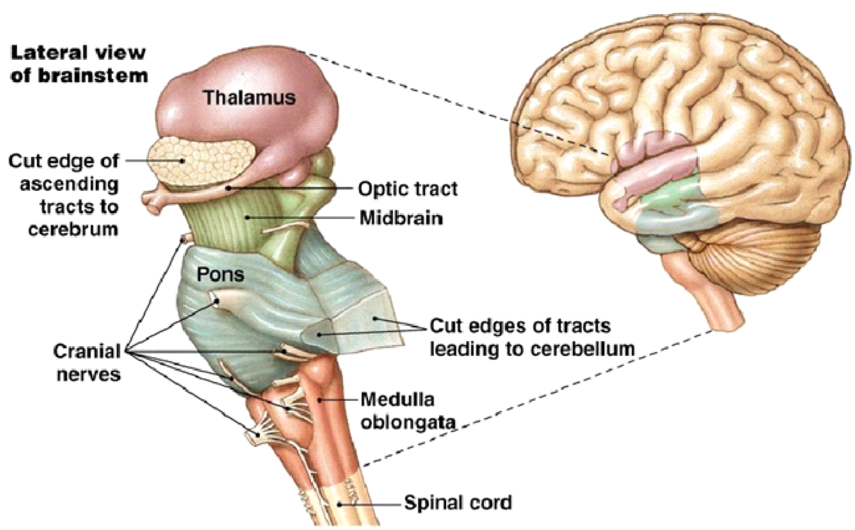

Figure 5.6

Cranial nerves are complex to understand as they can be sensory, motor or mixed (relaying both sensory and motor input), and may convey both sympathetic and parasympathetic fibres of the autonomic nervous system. In general, the cranial nerves of the brainstem are concerned with the senses of taste, hearing and balance, along with specialized motor activities, including chewing, swallowing, breathing, eye movements and facial expression.

The vagus nerve (derived from the Latin vagus meaning 'wandering') which has the most extensive distribution of any cranial nerve in the body) is somewhat different as it projects fibres to a variety of organs in the abdomen and thorax, including heart, lungs and digestive system. A consideration of the cranial nerves provide an interesting insight into the functions of the brainstem.

5.3.2 Mid brain

The midbrain (sometimes called the mesencephalon) is the name given to the region that forms the top part of the brainstem (Figure). It is generally divided into two areas: the tegmentum which is continuous with the pontine regions below it, and the tectum (meaning 'roof') which sits above it. The tegmentum contains several nuclei with important motor functions linked to basal ganglia function, including the red nucleus and substantia nigra.

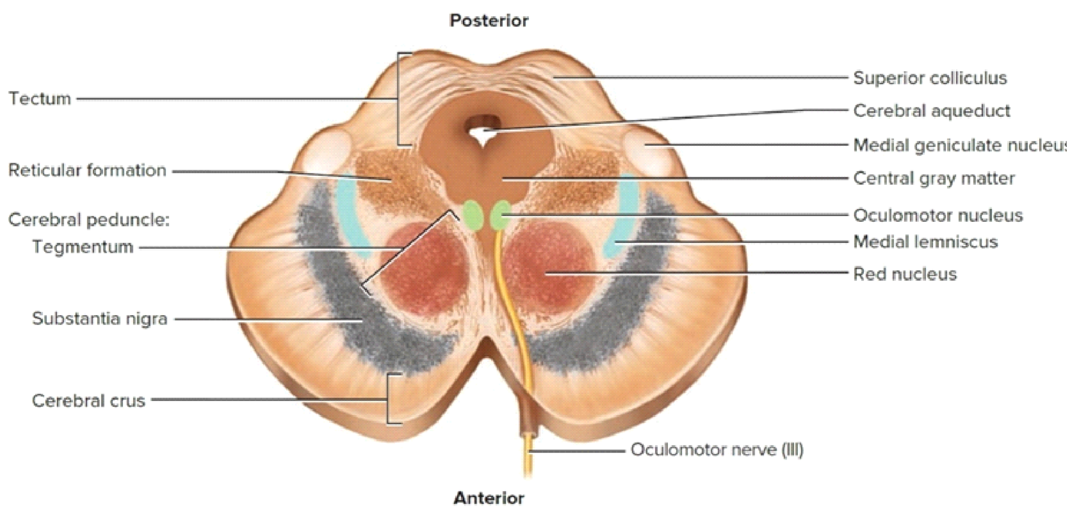

Figure 5.7

In addition, there are more diffuse areas of the tegmentum, including the periaqueductal grey area situated around the cerebral aqueduct (the passage connecting the third and fourth ventricles), and the ventral tegmental area which acts as an interesting crossroads – receiving descending input from the medial forebrain bundle, and returning information back to the forebrain (most notably striatum, limbic system and frontal cortex) via its dopaminergic pathways.

The tectum is actually the most recently evolved part of the brain, and it contains two pairs of nuclei called colliculi (derived from the Latin meaning 'small hills'), which protrude from its upper surface. These are the superior colliculi which are involved in visual processing and reflexes such as blinking and orientation, and inferior colliculi that serves a similar function for auditory processing. This part of the brain also gives rise to two more cranial nerves: the oculomotor controlling the muscles of the eyeball, and the trochlear involved in eye movement.

Also coursing through the centre of the brainstem and into the midbrain is the reticular activating system (RAS). This contains the ascending projections of the reticular formation, along with other areas of the brainstem, which passes to many areas of the forebrain, including the thalamus.

The RAS serves many essential functions, including the various stages of wakefulness and sleep. It also controls the level of electrical activity that governs states of arousal in the cerebral cortex (via its effect on the thalamus) which can be measured by using an electroencephalograph (EEG). The fibres making up the RAS are particularly complex and use a number of neurotransmitters, including noradrenaline, serotonin and acetylcholine.

5.3.3 Forebrain

Up to this point, the brain can be likened to a neural tube that has evolved and enlarged from the spinal cord. In fact, this is basically what happens during embryonic development. At first, the brain and spinal cord of every vertebrate animal appears as a tube which is only one cell thick. As it develops it begins to show three bulbous swellings called the primary brain vesicles. These can actually be observed in the human embryo by the fifth week of gestation. From bottom to top these are called the hindbrain (technically called the rhombencephalon) which becomes the brainstem; the mesencephalon which becomes the midbrain, and the forebrain.

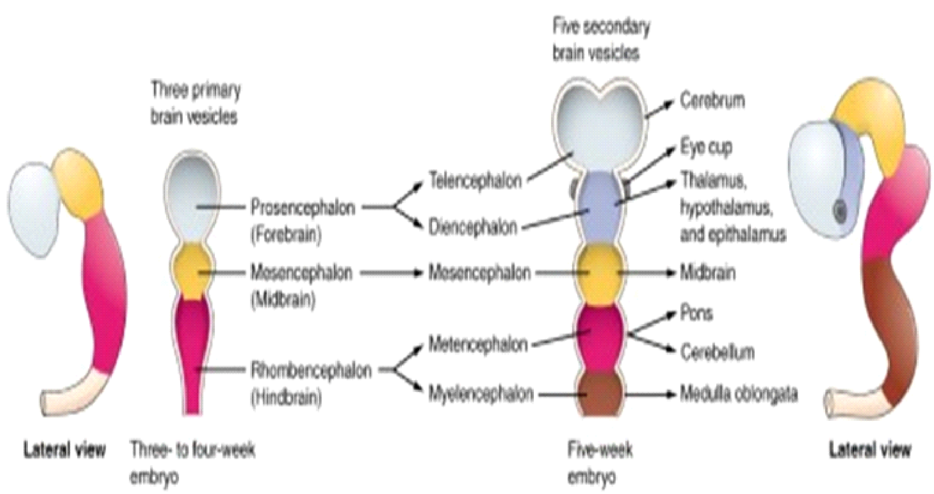

Figure 5.8

If we observe further development, we will see the forebrain ‘mushroom out’ so that it not only covers and surrounds much of the older ‘tubular’ brain but also adds greater complexity with the addition of many new structures. In fact, the forebrain will develop into two main regions: the diencephalon (literally ‘between-brain’), and telencephalon (‘endbrain’). The most important structures of the diencephalon are the thalamus and the hypothalamus.

5.3.3.1 Thalamus

The thalamus (from the Greek for ‘inner chamber’) consists of a symmetrical pair of egg-shaped structures that are separated medially by the third ventricle, and bounded laterally by a band of white fibres called the internal capsule that acts as the main communication link between the cerebral cortex and lower regions of the brain and spinal cord. The thalamus contains a bewildering number of different nuclei but are generally divided into anterior, medial, lateral and ventral groups.

Anatomically, the hypothalamus is very complex, with many different groups of nuclei, although it can be simplified by viewing it as having three zones. These are the preoptic area at the front, the medial zone which contains the majority of nuclei, and lateral nuclei which contain many of axons leaving the hypothalamus. In addition, the mammallary bodies are found at the back of the hypothalamus.

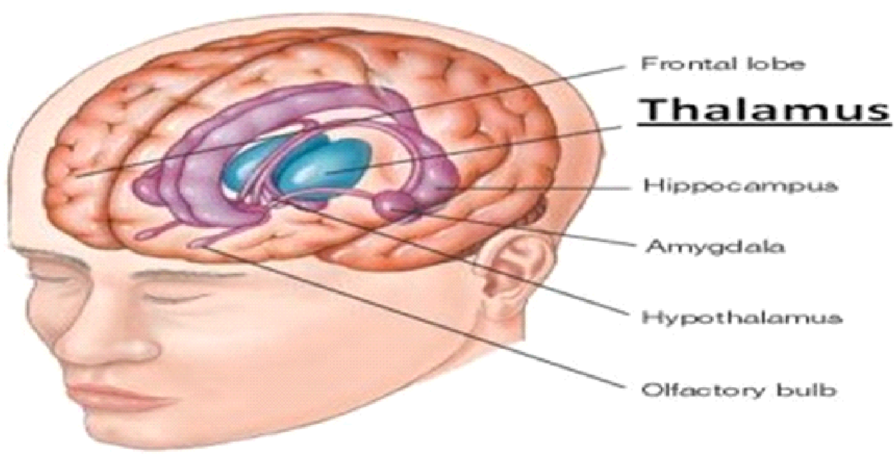

Figure 5.9

The thalamus has nerve connections with the cerebral cortex and hippocampus. In addition, connections with the spinal cord allow the thalamus to receive sensory information from the peripheral nervous system and various regions of the body. This information is then sent to the appropriate area of the brain for processing. It sends visual information to the visual cortex of the occipital lobes and auditory signals are sent to the auditory cortex of the temporal lobes

In general, the main function of the thalamus is to act as a relay station for information destined for the cerebral cortex. In this respect, its nuclei may either project to very precise locations (for example, the lateral geniculate bodies which project to the visual cortex), or have very diffuse ones that go to widespread areas of the cerebral cortex (for example, the intralaminar nuclei). The former are normally associated with a single sensory modality or motor system, whereas the latter appear to be involved in arousal.

5.3.3.2 Hypothalamus

Located just underneath the thalamus is a small structure making up only 0.15 per cent of the human brain called the hypothalamus (hypo meaning 'below'). Though it is small in size (it is roughly the size of a small grape), it plays a critical role in the maintenance of life as it controls both the autonomic and endocrine systems. In fact, destruction of the hypothalamus produce death in human.

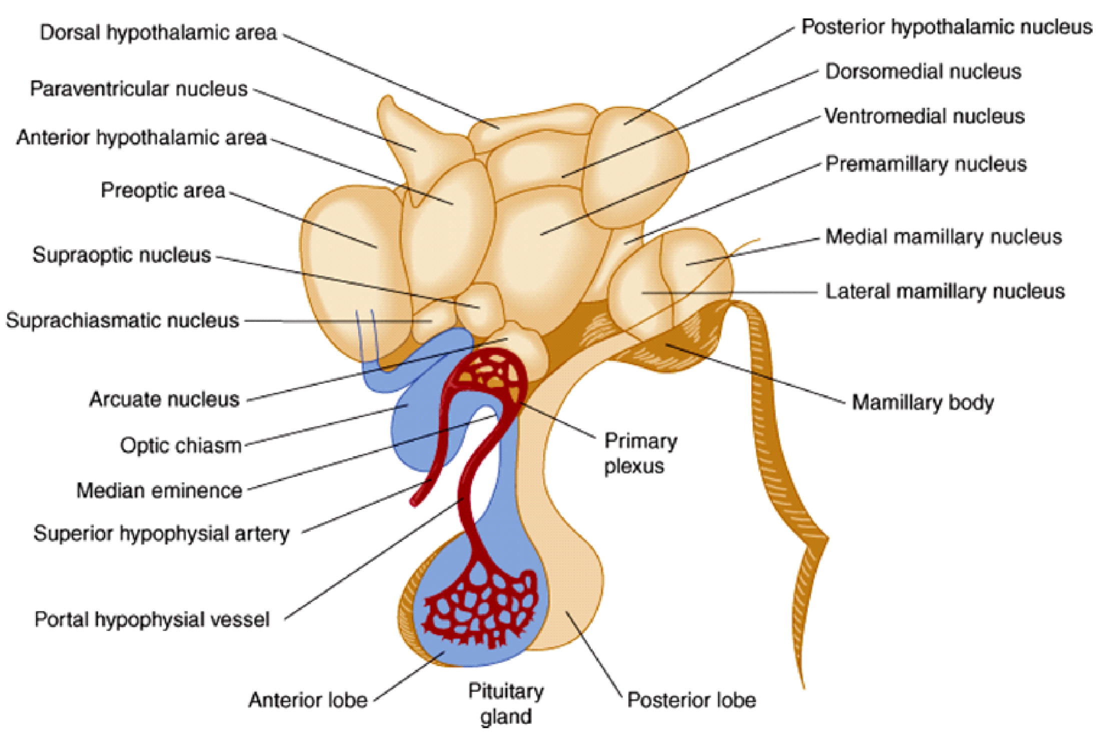

Figure 5.10

One of the most important functions of the hypothalamus is the co-ordination of homeostasis, that is, the ability of the body to maintain a constant internal environment despite continual exposure to various changes and external fluctuations. In addition, the hypothalamus has been described as the interface between our conscious brain, with its emotions and feeling, and the autonomic 'vegetative' processes of the body. The hypothalamus is also regarded as an integral part of the limbic system.

5.3.3.3 Limbic system

The word limbus comes from the Latin for 'border'; in 1878 Paul Broca applied the name to an area of the brain that surrounded the thalamus and striatum and appeared to separate the older brainstem from more recent cerebral cortex.

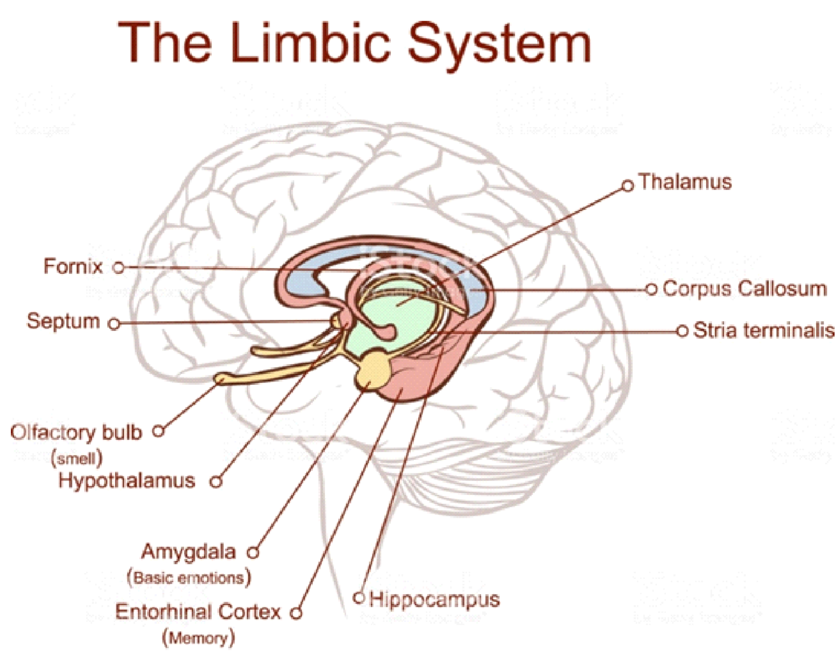

Figure 5.11

The limbic system plays a major role in producing drives, motivation and emotions. It also plays an important part in determining human behaviour – not least because it has been shown to be involved in producing the feelings of pleasure, anxiety and fear. The anatomy of the limbic system is complex and difficult to visualize. One of the most conspicuous structures of the limbic system is the hippocampus which is found in the medial aspects of the temporal lobe (Figure 5.11).

Partly surrounding the hippocampus is phylogenetically ‘old’ cortex, including the entorhinal cortex (which provides the perforant pathway into the hippocampus), Para hippocampal cortex and pyriform cortex. Another striking feature of the limbic system is the fornix, which is a massive (in humans it contains over 1 million fibres) long arching pathway that connects the hippocampus with the mammillary bodies and hypothalamus. The pathways are known to ascend from this part of the diencephalon via the anterior thalamus to the cingulate cortex.

The cingulate cortex wraps itself around the upper part of the corpus callosum, and contains a large bundle of fibres called the cingulum, which projects back to the hippocampus. Another important structure found in the limbic system is the amygdala which lies anterior to the hippocampus. This structure also has two descending pathways to the hypothalamus (the ventral amygdalofugal pathway and stria terminalis) and a pathway that projects to the prefrontal cortex via the mediodorsal nuclei of the thalamus.

5.3.3.4 Basal ganglia

The set of structures seen on the sideways of the thalamus comprise basal ganglia (literally meaning ‘basal nuclei’) (see Figure). The three main structures of the basal ganglia are the caudate nucleus (which also has a tail that curls over the top of the thalamus); the putamen which is separated from the caudate by the fibres of the internal capsule; and the globus pallidus (pale globe) which lies medial to the putamen. The caudate nucleus and putamen are also referred to as the corpus striatum – a term invented by Thomas Willis in 1664 who noted that this structure had a very distinct striated appearance of white and grey bands.

Two other structures generally regarded as important components of the basal ganglia are the substantia nigra which innervates the corpus striatum with dopaminergic neurons, and the subthalamic nucleus which has reciprocal connections with the globus pallidus. Traditionally, the basal ganglia have been considered as important structures of the extrapyramidal motor system (that is, the motor system of the brain whose output fibres do not cross in the pyramidal regions of the medulla).

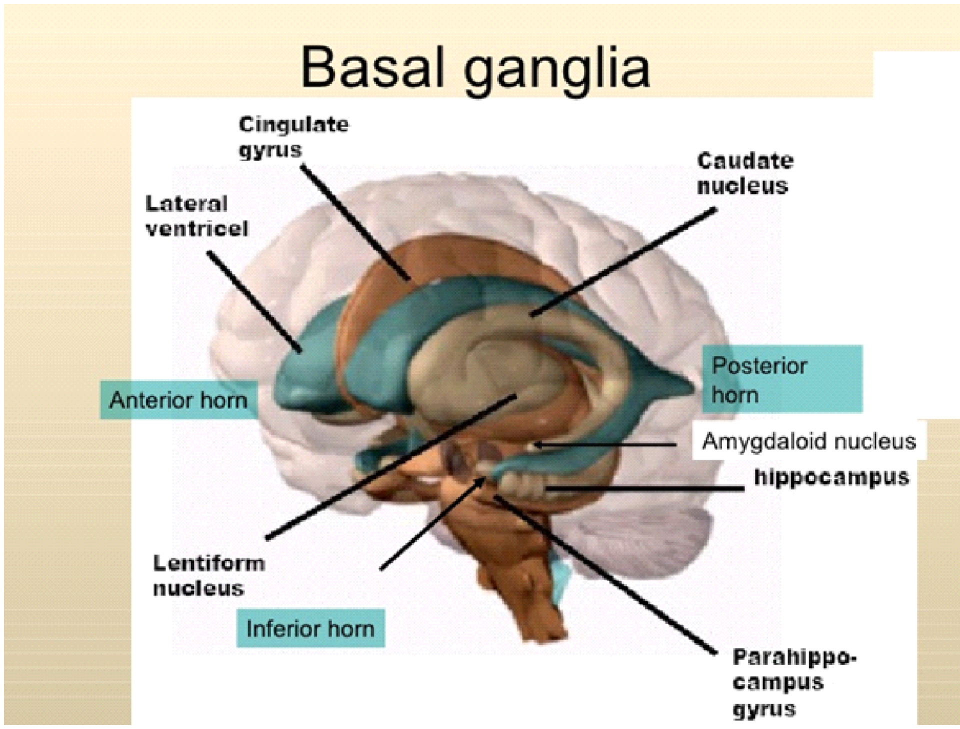

Figure 5.12

The most important functions of the basal ganglia can be discerned by examining the main symptoms of Parkinson's disease (rigidity, tremor and 'slow' movement) that are resulting from degeneration of the nigral–striatal pathway. Thus, the basal ganglia would appear to be involved in the co-ordination of motor activity, allowing it be automated (i.e. undertaken without 'thinking'), smooth and fluent. Although the nigral–striatal pathway is a significant projection to the corpus striatum, the largest projection actually derives from motor areas of the cerebral cortex which innervate the corpus striatum with fibres using the neurotransmitter glutamate.

In turn, the output fibres of both caudate and putamen project to, or pass through, the globus pallidus. From here, a major pathway travels back to the cerebral cortex via the ventral nuclei of the thalamus, with a smaller projection also going to the substantia nigra. The caudate nucleus, putamen and globus pallidus also have ventromedial extensions which extend deeper into the brain. In doing this, they appear to take on a more important role in emotional functions.

5.3.3.5 Cerebral cortex

The most striking feature of the human brain is undoubtedly the two symmetrical wrinkled cerebral hemispheres that form the cerebral cortex. This is truly remarkable structure which has been estimated to contain some 100,000 km of axons, and many millions of synapses. The cerebral cortex has a deceptive appearance: it is only around 2–3 mm thick, but is highly folded (not unlike a piece of paper that has been screwed up) which allows its large area to fit inside the small confines of the skull. In fact, if the cerebral cortex was flattened out its total surface area would be about 75 cm2 (2.5 ft2).

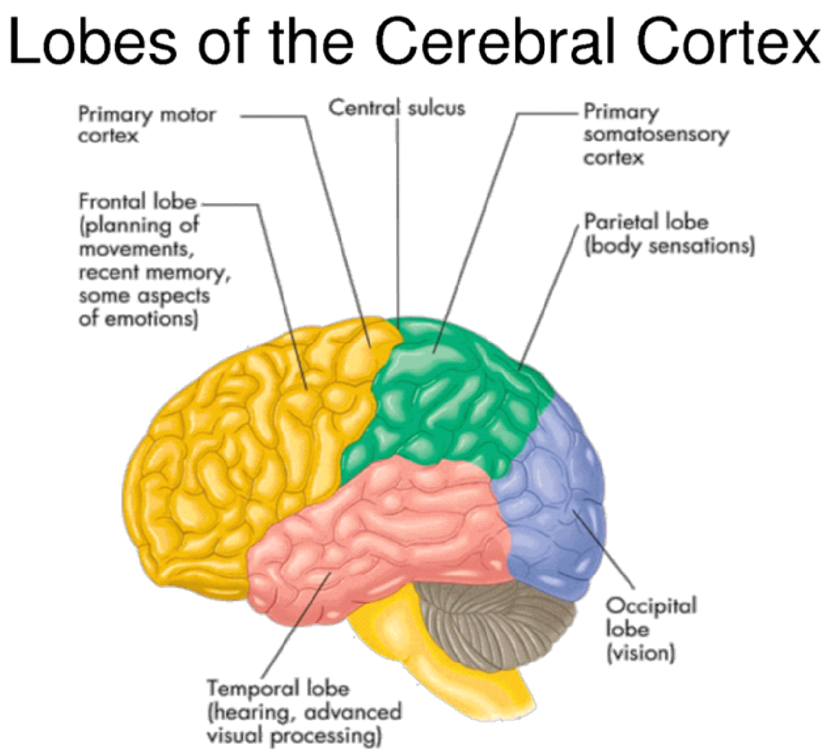

Figure 5.13

Because of this, about two-thirds of the cortex is hidden from view in fissures (or sulci) which are the gaps between the surface ridges (or gyri). The main fissures also make good surface landmarks to distinguish different regions of the cerebral cortex (Figure 5.13) For example, all the cortex anterior to the central fissure (sometimes called the Rolandic fissure) comprises the frontal lobe, whereas the tissue posterior to it forms the parietal lobe. Another sulcus called the parietal–occipital fissure separates the parietal lobe from the occipital lobe which is located at the back of the cerebral cortex.

The other main region of the cerebral cortex is the temporal lobe which is separated from the frontal and parietal lobes by the lateral fissure (sometimes called the Sylvian fissure). When examined under a high-powered microscope it can be seen that about 90 per cent of the cerebral cortex is made up of six layers (this is sometimes called neocortex) which is anatomically more complex than the more primitive three-layered cortex (archicortex) found mainly in parts of the limbic system.

In 1909, Brodmann divided the cerebral cortex into 52 different regions based on anatomical differences (now known as Brodmann's areas) and showed that this cortical organization was similar in all mammals. These anatomical differences reflect different functions that are undertaken by the cerebral cortex.

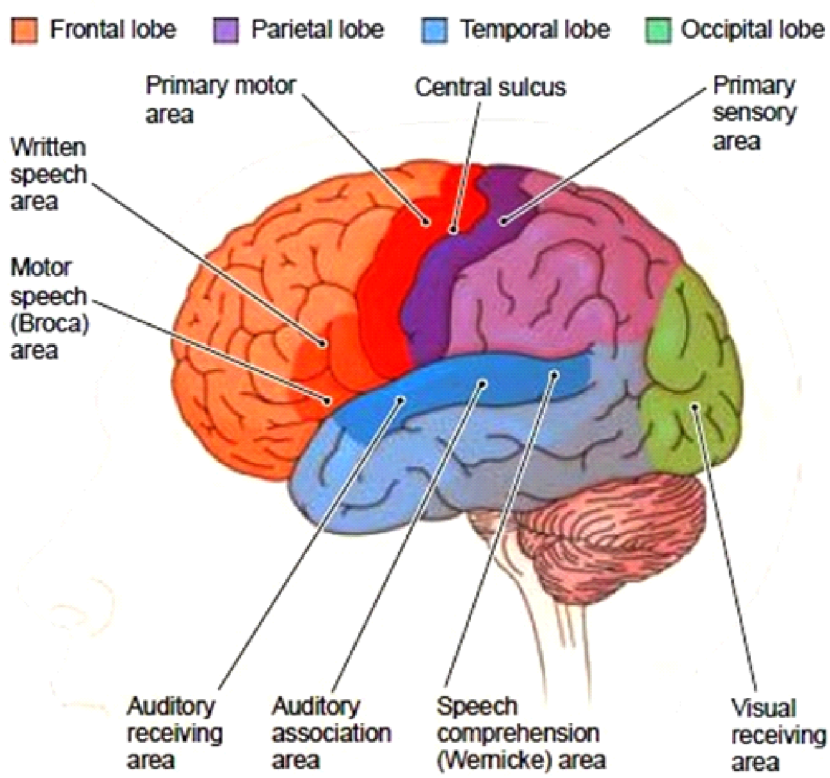

Figure 5.14

The functions served by the cerebral cortex are extremely varied. For example, the cerebral cortex contains the primary sensory areas that are specialized for receiving visual, auditory and somatosensory (touch) input. This information is relayed to the cortex by specific nuclei in the thalamus. In addition, the cerebral cortex contains a number of motor areas, including the primary motor cortex, located in the precentral gyrus of the frontal cortex, which controls voluntary movement.

The cerebral cortex also has a number of areas that are highly specialized for understanding and producing language. Despite this, most of the cerebral cortex in humans is actually made up of association areas – regions that are involved in the integration of many types of information. These regions are involved in many higher functions of the brain – and in abilities that underpin our ability to plan and see the consequences of our actions and to engage in various forms of abstract thought. It is also interesting to note that the right and left hemispheres also tend to show different types of cognition: the left being dominant for language and the right being dominant for spatial processing. The two cerebral hemispheres communicate with each other by a huge fibre bundle called the corpus callosum which contains around 300 million axons.

5.4 Functions of major Brain areas

The brain is comprised of a number of different regions, each with specialized functions. The brain's central core, includes the brain stem and the midbrain, and is quite different than the cerebral cortex that envelops it. The central core is relatively simple, older and its activity is largely unconscious. In contrast, the cortex is highly developed and capable of the deliberation and associations necessary for complex thinking and problem solving. In humans, its size and function has increased rapidly. While the older portions of the brain remain relatively static.

5.4.1 THE BRAIN STEM

The brain stem seems to be inherited almost "as is" from the reptilian brain. It consists of structures such as the medulla (controlling breathing, heart rate, and digestion) and the cerebellum (which coordinates sensory input with muscle movement).

5.4.2 THE MIDBRAIN

The Midbrain includes features that appear intimately connected to human emotion and to the formation of long-term memory via neural connections to the lobes of the neocortex. The structures contained here also link the lower brain stem to the thalamus — for information relay from the senses, to the brain, and back out to muscles — and to the limbic system. The limbic system, essentially alike in all mammals, lies above the brain stem and under the cortex. It consists of a number of interrelated structures. The limbic system is linked to hormones, drives, temperature control, and emotion. One part is dedicated to memory formation, thus explaining the strong link between emotion and long term memory.

The limbic system includes these parts:

- The hypothalamus is instrumental in regulating drives and actions. Neurons affecting heart rate and respiration are concentrated here. These direct most of the physical changes that accompany strong emotions, such as the “flight or fight” response.
- The amygdala appears connected to aggressive behavior.
- The hippocampus plays a crucial role in processing various forms of information to form long-term memories. Damage to the hippocampus will produce global retrograde amnesia. One very important feature of the midbrain and limbic system is the reticular activating system (RAS). It is this area that keeps us awake and aware of the world. The RAS acts as a master switch that alerts the brain to incoming data — and to the urgency of the message.

5.4.3 THE FOREBRAIN OR NEOCORTEX

The forebrain, which appears as a mere bump in the brain of a frog, balloons out into the cerebrum of higher life forms and covers the brain stem like the head of a mushroom. This, the newest part of the human brain, is also called the neocortex, or cerebral cortex. The structure of the neocortex is very complicated and most of the higher level functions associated with human thought are enabled in this region. We now turn to some specific parts of the cortex. The areas of the cerebral cortex is divided based on the structure and function of cells. For convenience, these areas are grouped into four lobes named for the skull bones that lie over them: occipital, parietal, temporal, and frontal.

5.4.3.1 Frontal Lobes

The frontal lobes occupy the front part of the brain. It contains the primary motor cortex and the prefrontal cortex, extending from the central sulcus to the anterior limit of the brain. The posterior portion of the frontal lobe just anterior to the central sulcus, the precentral gyrus, is specialized for the control of fine movements, such as moving one finger at a time. Separate areas are responsible for different parts of the body, mostly on the contra lateral (opposite) side but also with slight control of the ipsilateral (same) side. The most anterior portion of the frontal lobe is the prefrontal cortex. In general, the larger a species' cerebral cortex, the higher the percentage of it is devoted to the prefrontal cortex. The dendrites in the prefrontal cortex have up to 16 times as many dendritic as neurons in other cortical areas. As aresult, the prefrontal cortex integrates an enormous amount of information.

The functions of frontal lobes are associated with making decisions, planning, and voluntary muscle movement. Speech, smell, and emotions are processed here as well. The frontal lobes control our responses and reactions to input from the rest of the system. The saying "Get your brain in gear" refers to activity in the frontal lobes.

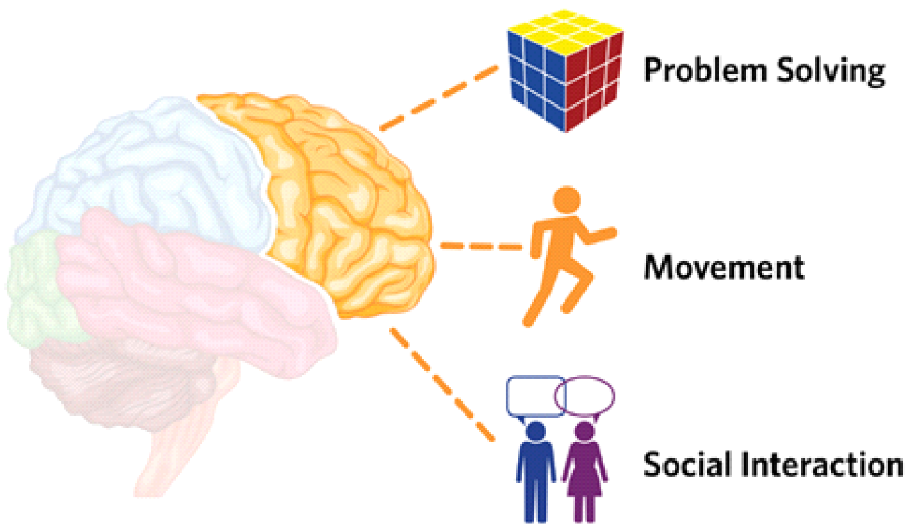

Figure 5.15

5.4.3.2 Parietal Lobes

The parietal lobe lies between the occipital lobe and the central sulcus, which is one of the deepest grooves in the surface of the cortex. The area just posterior to the central sulcus, the postcentral gyrus, or primary somatosensory cortex, is the main target for touch sensations and information from muscle-stretch receptors and joint receptors. The postcentral gyrus includes four bands of cells parallel to the central sulcus. Separate areas along each band receive simultaneous information from different parts of the body. Two of the bands receive mostly light-touch information, one receives deep-pressure information, and one receives a combination of both.

The parietal lobes are most closely associated with our sense of touch. They contain a detailed map of the whole body's surface. More neurons are dedicated to some regions of surface area than others. For example, the fingers have many more nerve endings than the toes, and therefore they have more associated areas in the brain for processing. Information about touch and body location is important not only for its own sake but also for interpreting visual and auditory information. For example, if you see something in the upper left portion of the visual field, your brain needs to know which direction your eyes are turned, the position of your head, and the tilt of your body before it can determine the location of the object that you see and therefore your direction if you want to approach or avoid it. The parietal lobe monitors all the information about eye, head, and body positions and passes it on to brain areas that control movement.

DIGRAMATIC REPRESENTAION OF PARIETAL LOBE FUNCTIONS

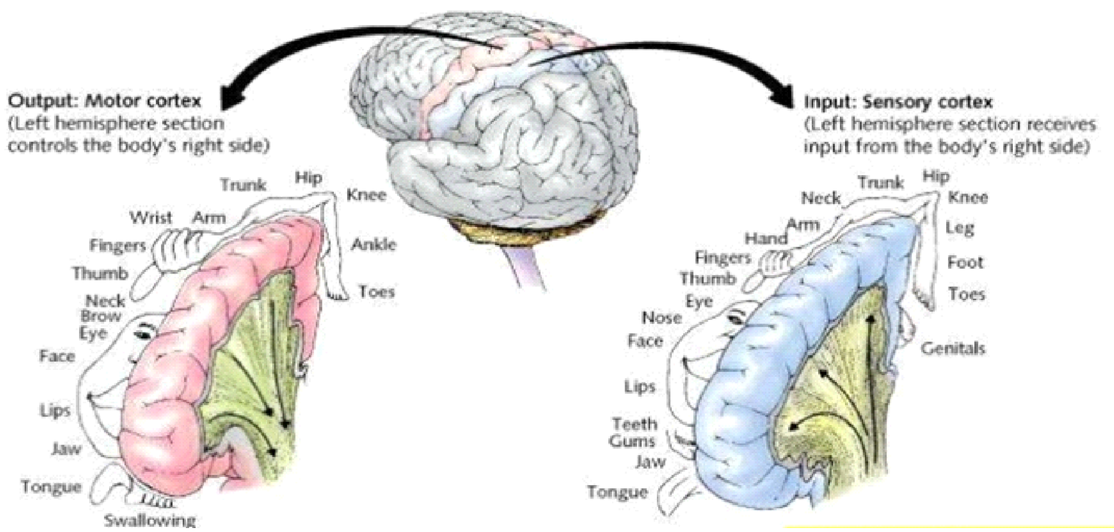

Figure 5.16

The parietal lobe of the right hemisphere appears to be especially important for perceiving spatial relationships. The recognition of relationships between objects in space is important to activities such as drawing, finding your way, construction, and mechanical or civil engineering. It is essential not only for spatial information but also numerical information.

5.4.3.3 Temporal Lobes

The temporal lobes are concerned with emotions, and also contain the primary auditory cortex, which processes soundThe temporal lobe is the lateral portion of each hemisphere, near the temples. It is the primary cortical target for auditory information. The human temporallobe—in most cases, the left temporal lobe—is essential for understanding spoken language. The temporal lobe also contributes to complex aspects of vision, including perception of movement and recognition of faces. A tumor in the temporal lobe may give rise to elaborate auditory or visual hallucinations, whereas a tumor in the occipital lobe ordinarily evokes only simple sensations, such as flashes of light.

The temporal lobes also play a part in emotional and motivational behaviors. Temporal lobe damage can lead to a set of behaviors known as the Klüver-Bucy syndrome (named for the investigators who first described it). Previously wild and aggressive monkeys fail to display normal fears and anxieties after temporal lobe damage (Klüver & Bucy, 1939). They put almost anything they find into their mouths and attempt to pick up snakes and lighted matches (which intact monkeys consistently avoid). Interpreting this behavior is difficult. For example, a monkey might handle a snake because it is no longer afraid (an emotional change) or because it no longer recognizes what a snake is (a cognitive change).

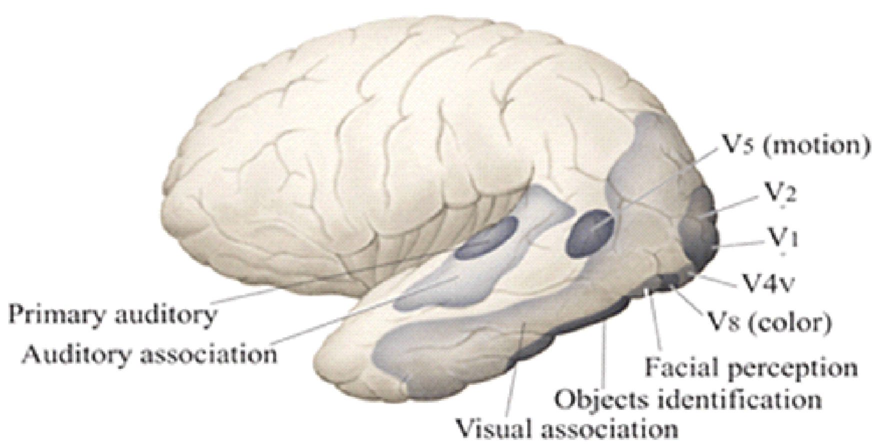

Figure 5.17

5.4.4.4 Occipital Lobes

The occipital lobes are the primary visual cortex. This area at the back of the brain, just above the cerebellum, processes stimuli from our eyes, via the optic nerve, and associates that information with other sensory input and memories. The posterior pole of the occipital lobe is known as the primary visual cortex, or striate cortex, because of its striped appearance in cross-section. Destruction of any part of the striate cortex causes cortical blindness in the related part of the visual field. For example, extensive damage to the striate cortex of the right hemisphere causes blindness in the left visual field (the left side of the world from the viewer's perspective).

A person with cortical blindness has normal eyes, normal pupillary reflexes, and some eye movements but no pattern perception or visual imagery. People who suffer eye damage become blind, but if they have an intact occipital cortex and previous visual experience, they can still imagine visual scenes and can still have visual dreamsRecall that areas crucial to long-term memory also reside at the back of the brain. These association areas interpret sensory data by relating it to existing knowledge, and are essential to memory formation.. The occipital lobe, located at the posterior (caudal) end ofthe cortex, is the main target for visual information.

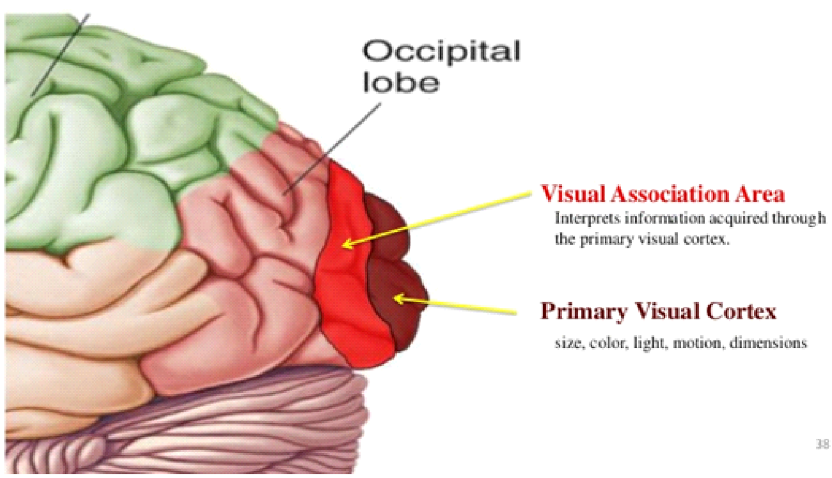

Figure 5.18

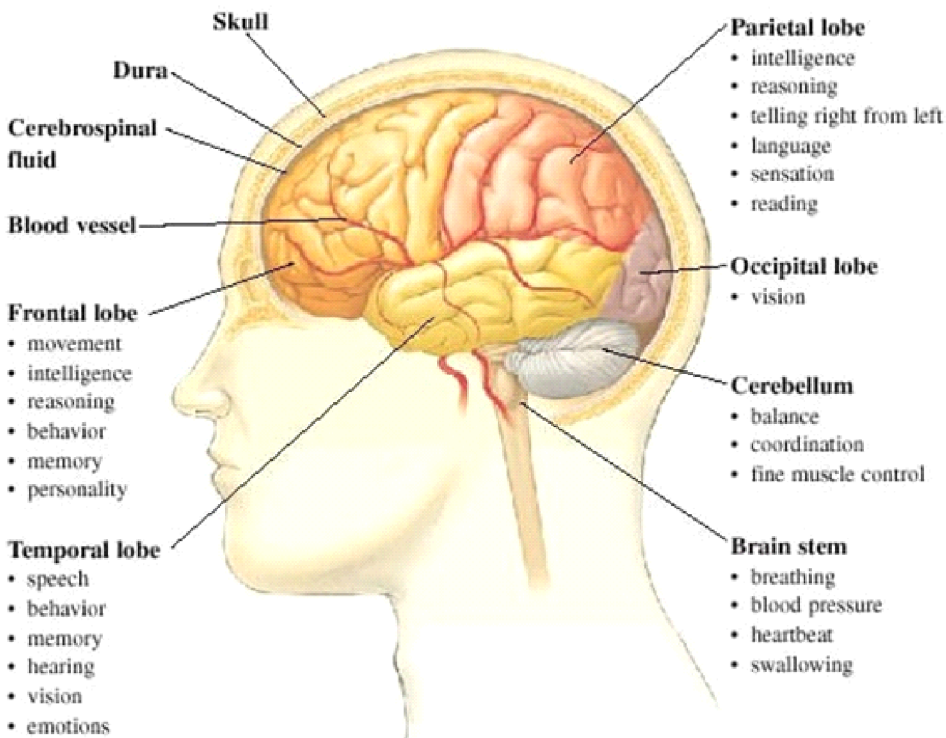

Figure 5.19

5.4.4.5 Sensory Cortex and Motor Cortex

Regions called the sensory cortex and the motor cortex are sandwiched between the frontal and parietal lobes, right at the top of the head. These areas specialize in the control of movement and in receiving information from the body's primary sensory systems (vision, smell, taste, touch, and sound).

Thus the frontal lobe of the neocortex appears to be responsible for planning, decision-making, and risk-taking while the back of the brain stores memories. The middle section is focused on experiencing the present moment, since it houses the primary sensory and motor cortex. It is busily processing information from our five senses and sending control signals back out to our muscles.

5.5 Conclusion

The human brain is a very complex and interesting organ in the human body. The brain has three basic units that are all responsible for its own distinct functional role of the body; brain and spinal cord are the two main structures of the central nervous system, the three units of the brain are the hindbrain, midbrain, and the forebrain. With each region of the brain, there are specific ones that have their main roles that help guide cognitive functions. The brain helps humans to organize, retrieve, make sense out of the information we process every day with the use of the various regions of our brain that work together as well as independently. Knowledge of the brain functions gives a better understanding for how humans are so much alike, yet can behave, and react to similar stimuli in completely different ways.

5.6 SUMMARY

The main divisions of the vertebrate nervous system are the central nervous system and the peripheral nervous system. Each segment of the spinal cord has a sensory nerve on each side and a motor nerve on each side. Spinal pathways convey information to the brain. The central nervous system consists of the spinal cord, the hindbrain, the midbrain, and the forebrain. The hindbrain consists of the medulla, pons, and cerebellum. The medulla and pons control breathing, heart rate, and other vital functions through the cranial nerves. The cerebellum contributes to movement and timing short intervals. The cerebral cortex receives its sensory information (except for olfaction) from the thalamus. The subcortical areas of the forebrain include the thalamus, hypothalamus, pituitary gland, basal ganglia, and hippocampus. Although brain size varies among mammalian species, the overall organization is similar.

The occipital lobe of the cortex is primarily responsible for vision. Damage to part of the occipital lobe leads to blindness in part of the visual field. The parietal lobe processes body sensations. The postcentral gyrus contains four separate representations of the body. The temporal lobe contributes to hearing, complex aspects of vision, and processing of emotional information. The frontal lobe includes the precentral gyrus, which controls fi ne movements. It also includes the prefrontal cortex, which contributes to memories of current and recent stimuli, planning of movements, and regulation of emotional expressions. The prefrontal cortex is important for working memory and for planning actions that depend on the context.

5.7 KEY WORDS

::autonomic nervous system

controls the heart, the intestines, and other organs.

::basal ganglia

a group of subcortical structures lateral to the thalamus, include three major structures: the caudate nucleus, the putamen, and the globus pallidus

::brainstem

The medulla and pons, the midbrain, and certain central structures of the forebrain constitute the brainstem

::central nervous system (CNS)

the brain and the spinal cord

::cerebellum

a large hindbrain structure with many deep folds.

::cranial nerves

control sensations from the head, muscle movements in the head, and much of the parasympathetic output to the organs

::dorsal

toward the back

::dorsal root ganglia

clusters of neurons outside the spinal cord

::forebrain

the most anterior and most prominent part of the mammalian brain.

::gray matter

dense package with cell bodies and dendrites.

::hindbrain

the posterior part of the brain, consists of the medulla, the pons, and the cerebellum.

::hippocampus

a large structure between the thalamus and the cerebral cortex.

::hypothalamus

a small area near the base of the brain just ventral to the thalamus

::inferior colliculus

midbrain nucleus of the auditory pathway and receives input from several peripheral brainstem nuclei in the auditory pathway, as well as inputs from the auditory cortex.

::limbic system

A number of interlinked structures, forming a border around the brainstem.

::medulla

a cone-shaped neuronal mass responsible for autonomic (involuntary) functions ranging from vomiting to sneezing.

::midbrain

the middle of the brain

::peripheral nervous system (PNS)

the nerves and ganglia outside the brain and spinal cord.

::Pituitary gland

an endocrine (hormone-producing) gland attached to the base of the hypothalamus

::pons

Part of the midbrain lying inferior to the midbrain, superior to the medulla oblongata and anterior to the cerebellum.

::spinal cord

a long, thin, tubular bundle of nervous tissue and support cells that extends from the medulla oblongata in the brainstem to the lumbar region of the vertebral column.

::substantia nigra

structure in the midbrain

::superior colliculus

a paired structure of the mammalian midbrain.

::tectum

The roof of the midbrain

::tegmentum

the intermediate level of the midbrain.

::thalamus

a pair of structures (left and right) in the center of the forebrain

::cerebral cortex

The most prominent part of the mammalian brain , consisting of the cellular layers on the outer surface of the cerebral hemispheres.

::corpus callosum

a thick band of nerve fibers that divides the cerebral cortex lobes into left and right hemispheres.

::frontal lobe

the part of the brain that controls important cognitive skills in humans, such as emotional expression, problem solving, memory, language, judgment, and sexual behaviors.

::Klüver-Bucy syndrome

a neuro-behavioral syndrome associated with bilateral lesions in the anterior temporal horn or amygdala.

::occipital lobe

located in the back portion of the brain behind the parietal and temporal lobes, and is primarily responsible for processing visual information .

::parietal lobe

positioned above the temporal lobe and behind the frontal lobe and central sulcus

::postcentral gyrus

gyrus in the lateral parietal lobe of the human brain and is the location of the primary somatosensory cortex.

::precentral gyrus

the primary motor cortex, is a very important structure involved in executing voluntary motor movements.

::temporal lobe

the lateral portion of each cerebral hemisphere, near the temples

5.8 CHECK YOUR PROGRESS

1. The central nervous system (CNS) contains
   - (a) Brain and cranial nerves
   - (b) Spinal cord and spinal nerves
   - (c) Brain and spinal cord
   - (d) Cranial and spinal nerves

2. What is the greatest evolutionary change in the human brain?
   - (a) Overall size
   - (b) Overall weight
   - (c) Enlargement of the cerebrum
   - (d) Elongation of the brainstem

3. What is the role of the corpus collosum?
   (a) Center of the executive functions
   (b) Connects the two hemispheres of the brain
   (c) Coordination of motor movements
   (d) Determines handedness in humans

4. Which part of the brain controls balance and coordinates movements?
   (a) Medulla
   (b) Thalamus
   (c) Hypothalamus
   (d) Cerebellum

5. Lobe controlling vision is
   (a) Occipital
   (b) Frontal
   (c) Temporal
   (d) Parietal

6. Lobe controlling auditory and hearing function is
   (a) Occipital
   (b) Parietal
   (c) Temporal
   (d) Frontal

5.9 ANSWERS TO CHECK YOUR PROGRESS

1. (c)
2. (c)
3. (b)
4. (d)
5. (a)
6. (c)

5.10 MODEL QUESTIONS

1. Explain the anatomical and functional divisions of the central nervous system
2. Trace out the basic structure of the spinal cord
3. What are the basic structure of brain?
4. Explain the basic functions of the central nervous system.

LESSON 6
SENSORY ORGANS

INTRODUCTION

In the completed lessons, how the communication of information inside the human body takes place and the structures involved for this communication to happen, were dealt in detail. In order to communicate, the information about the world has to have a way to get into the brain, where it can be used to determine actions and responses. The way into the brain is through the sensory organs and the process of sensation. This lesson deals with the sensory organs.

LEARNING OBJECTIVES

At the end of this unit you will be able to understand

- the characteristics of sensory modalities
- the nature of sense organs
- he structure of sense organs

PLAN OF THE LESSON

6.1 Sensation

6.2 Nature and Varieties of Stimulus

6.3 Sensory Receptors

6.4 Sensory Threshold

6.5 Habituation and Sensory adaptation

6.6 The Structure of the Eye

6.7 The Structure of the Ear

6.8 Chemical Senses

6.9 The Sense of Scents: Olfaction

6.10 Somesthetic Senses

6.11 Conclusion

6.1 Sensation

Our picture of the world around us depends on an elaborate sensory system that processes incoming information. In other words, we experience the world through a series of "filters" that we call our senses .Sensation is very basic. Sensation involves all those processes that are necessary for the basic detection that something exists in the world. For example, a sensory process might be detecting the loudness of a sound or the type of taste in a food.

Sensation and Perception

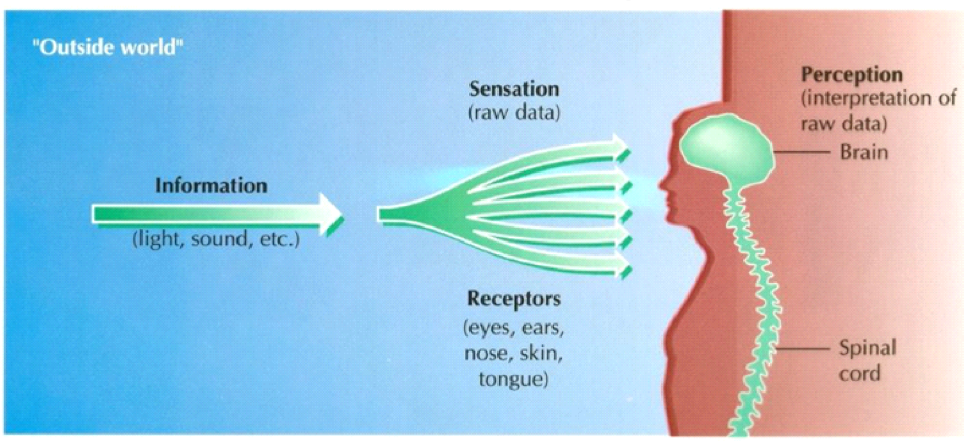

Figure 6.1

sensation is defined as the simple process by which a stimulated receptor (such as the eyes or ears) creates a pattern of neural messages that represent the stimulus in the brain, giving rise to our initial experience of the stimulus. Sensation occurs when special receptors in the sense organs—the eyes, ears, nose, skin, and taste buds—are activated, allowing various forms of outside stimuli to become neural signals in the brain. (This process of converting outside stimuli, such as light, into neural activity is called transduction.) Sensation is the process whereby a physical stimulus produces physiological reactions that eventually lead to a subjective, psychological experience (Figure 6.1). Sensation is the raw, unanalysed experience, before perceptual processes interpret the evoked experience. All of our sensory systems require receptors. These are unique neural structures that react to particular forms of physical stimulation.

6.2 Nature and Varieties of Stimulus

The external environment that surrounds us contains a wide variety of stimuli. Some of them can be seen (e.g., a house), while some can be heard only (e.g., music). There are several others that we can smell (e.g., fragrance of a flower) or taste (e.g., sweets). There are still others that we can experience by touching (e.g., softness of a cloth). All these stimuli provide us with various kinds of information.

We have very specialized sense organs to deal with these different stimuli. As human beings we are bestowed with a set of seven sense organs. These sense organs are also known as sensory receptors or information gathering systems, because they receive or gather information from a variety of sources. Five of these sense organs collect information from the external world. These are eyes, ears, nose, tongue, and skin. While our eyes are primarily responsible for vision, ears for hearing, nose for smell, and tongue for taste, skin is responsible for the experiences of touch, warmth, cold, and pain. Specialised receptors of warmth, cold, and pain are found inside our skin. Besides these five external sense organs, we have also got two deep senses. They are called kinesthetic and vestibular systems. They provide us with important information about our body position and movement of body parts related to each other. With these seven sense organs, we register ten different variety of stimuli.

6.3 Sensory Receptors

The sensory receptors are specialized forms of neurons, the cells that make up the nervous system. (Table 6.1)

Instead of receiving neurotransmitters from other cells, these receptor cells are stimulated by different kinds of energy—for example, the receptors in the eyes are stimulated by light, whereas the receptors in the ears are activated by vibrations. Touch receptors are stimulated by pressure or temperature, and the receptors for taste and smell are triggered by chemical substances. The different types of sensory receptors are (a) Mechanoreceptors, (b) Chemoreceptors, (c) Electromagnetic receptors and (d) Photoreceptors.(Diagram 6.1)

Sense	Stimulus	Sense Organ	Receptor	Sensation
Sight	Light waves	Eye	Rods and cones of retina	Colors, patterns, textures, motion, depth in space
Hearing	Sound waves	Ear	Hair cells located in inner ear	Noises, tones
Skin sensations	External contact	Skin	Nerve endings in skin	Touch, pain, warmth, cold
Smell	Volatile substances	Nose	Hair cells of olfactory membrane	Odors (musky, flowery, burnt, minty)
Taste	Soluble substances	Tongue	Taste buds of tongue	Flavors (sweet, sour, salty, bitter)
Vestibular sense	Mechanical and gravitational forces	Inner ear	Hair cells of semicircular canals and vestibule	Spatial movement, gravitational pull
Kinesthesis	Body movement	Muscles, tendons,	Nerve fibers in muscles, tendons, and joints	Movement and position of body parts

Table 6.1

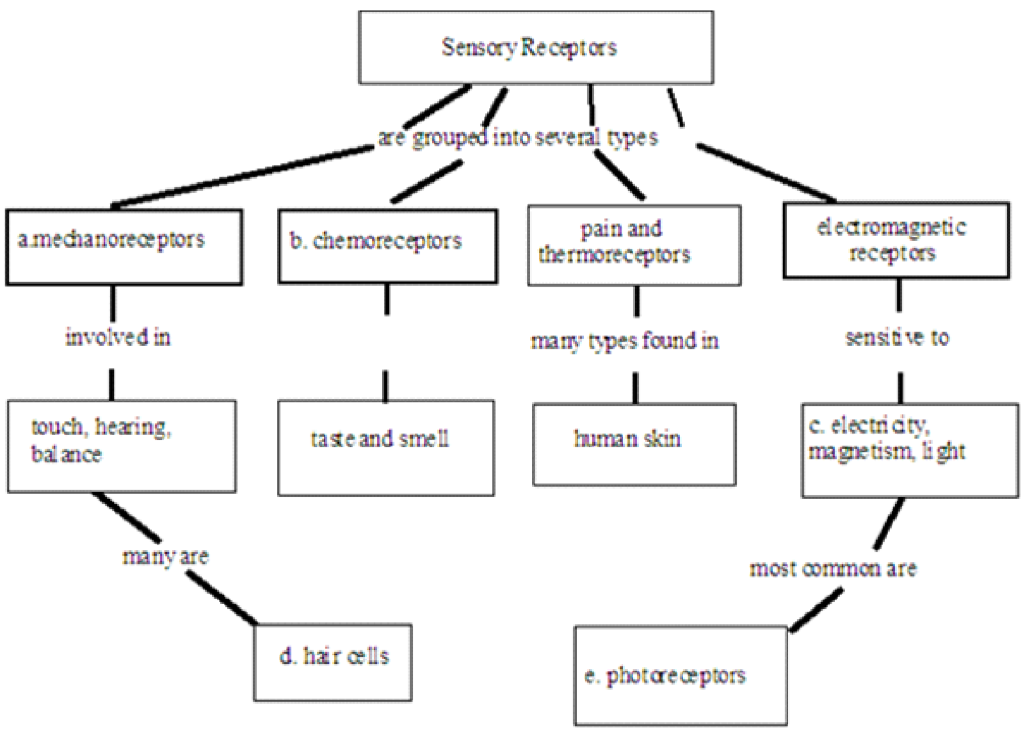

Diagram 6-.1

6.4 Sensory Threshold

Before we move on to a discussion of sense organs, it is important to understand that our sense organs function with certain limitations. For example, our eyes cannot see things which are very dim or very bright. Similarly our ears cannot hear very faint or very loud sounds. The same is true for other sense organs also. As human beings, we function within a limited range of stimulation. For being noticed by a sensory receptor, a stimulus has to be of an optimal intensity or magnitude. The relationship between stimuli and the sensations they evoke has been studied in a discipline, called psychophysics.

A stimulus has to carry a minimum value or weight in order to be noticed. The minimum value of a stimulus required to activate a given sensory system is called absolute threshold or absolute limen (AL). For example, adding a granule of sugar to a glass of water, sweetness in that water may not be experienced. Addition of a second granule to water may also not make it taste sweet. But if sugar granules are added one after another continuously, there will come a point when you will experience the sweetness in the water. The minimum number of sugar granules required to say that the water is sweet will be the absolute threshold of sweetness. Absolute threshold is not a fixed point; instead it varies considerably across individuals and situations depending on the people's organic conditions and their motivational states. Hence, it has to be assessed on the basis of a number of trials. The number of sugar granules that may produce the experience of "sweetness" in water on 50 per cent of occasions will be called the AL of sweetness. If more number of sugar granules are added, the chances are greater that the water will be reported more often as sweet than plain.

As it is not possible for us to notice all stimuli, it is also not possible to differentiate between all stimuli. In order to notice two stimuli as different from each other, there has to be some minimum difference between the value of those stimuli. Ernst Weber (1795–1878) did studies trying to determine the smallest difference between two weights that could be detected. His research led to the formulation known as Weber's law of just noticeable differences (**jnd**, or the difference threshold).

A **jnd** is the smallest difference between two stimuli that is detectable 50 percent of the time, and Weber's law simply means that whatever the difference between stimuli might be, it is always a constant. If to notice a difference the amount of sugar a person would need to add to a cup of coffee that is already sweetened with 5 teaspoons is 1 teaspoon, then the percentage of change needed to detect a just noticeable difference is one-fifth, or 20 percent. So if the coffee has 10 teaspoons of sugar in it, the person would have to add another 20 percent, or 2 teaspoons, to be able to taste the difference half of the time. The smallest difference in the value of two stimuli that is necessary to notice them as different is called **difference threshold** or **difference limen** (DL). The understanding of sensations is not possible without understanding the AL and DL of different types of stimuli (for example, visual, auditory).

Stimuli that are below the level of conscious awareness are called subliminal stimuli. (The word limin means "threshold," so sublimin means "below the threshold.") These stimuli are just strong enough to activate the sensory receptors but not strong enough for people to be consciously aware of them. Many people believe that these stimuli act upon the unconscious mind, influencing behavior in a process called subliminal perception. There is a growing body of evidence that we process some stimuli without conscious awareness, especially stimuli that are fearful or threatening.

6.5 Habituation and Sensory adaptation

From previous lessons it was learned that the lower centers of the brain filters the sensory stimulation and "ignore" or prevent conscious attention to stimuli that do not change. The brain is only interested in changes in information. That's why people don't really "hear" the noise of the air conditioner unless it suddenly cuts off or the noise made in some classrooms unless it gets very quiet. Although they actually are hearing it, they aren't paying attention to it. This is called habituation, and it is the way the brain deals with unchanging information from the environment.

Sometimes the odor of the garbage can be felt in the kitchen when you first come home, but after a while the smell seems to go away. Though it is similar to habituation, this is called sensory adaptation. Sensory adaptation is another process by which constant, unchanging information from the sensory receptors is effectively ignored.

In habituation, the sensory receptors are still responding to stimulation but the lower centers of the brain are not sending the signals from those receptors to the cortex. The process of sensory adaptation differs because the receptor cells themselves become less responsive to an unchanging stimulus—garbage odors included—and the receptors no longer send signals to the brain. For example, when we eat, the food that we put in our mouth tastes strong at first, but as we keep eating the same thing, the taste does fade somewhat.

Smell, taste, and touch are all subject to sensory adaptation. You might think, then, that if you stare at something long enough, it would also disappear, but the eyes are a little different. Even though the sensory receptors in the back of the eyes adapt to and become less responsive to a constant visual stimulus, under ordinary circumstances the eyes are never entirely still. There's a constant movement of the eyes, tiny little vibrations called "micro saccades" or "saccadic movements" that people don't consciously notice. These movements keep the eyes from adapting to what they see.

6.6 The Structure of the Eye

The surface of the eye is covered in a clear membrane called the cornea. The cornea not only protects the eye but also is the structure that focuses most of the light coming into the eye. The cornea has a fixed curvature, like a camera that has no option to adjust the focus. The next visual layer is a clear, watery fluid called the aqueous humor. This fluid is continually replenished and supplies nourishment to the eye.

The light from the visual image then enters the interior of the eye through a hole, called the pupil, in a round muscle called the iris (the colored part of the eye). The iris can change the size of the pupil, letting more or less light into the eye. That also helps focus the image; people try to do the same thing by squinting. Behind the iris, suspended by muscles, is another clear structure called the lens. After the lens, there is a large, open space filled with a clear, jelly-like fluid called the vitreous humor. This fluid, like the aqueous humor, also nourishes the eye and gives it shape.

6.6.1 Retina, rods, cones and blind spot

The final stop for light within the eye is the retina, a light sensitive area at the back of the eye containing three layers: ganglion cells, bipolar cells, and the rods and cones, special cells (photoreceptors) that respond to the various light waves. There is a "hole" in the retina—the place where all the axons of those ganglion cells leave the retina to become the optic nerve. There are no rods or cones here, so this is referred to as the blind spot.

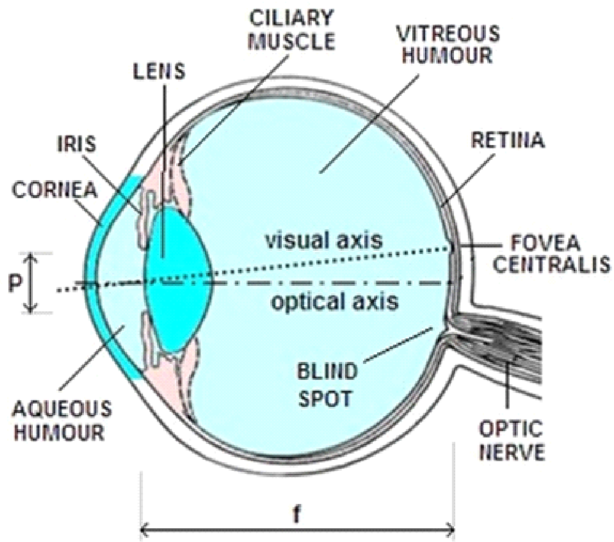

Figure 6.2

6.7 The Structure of the Ear

The properties of sound are indeed similar to those of light, as both senses rely on waves. But the similarity ends there, as the physical properties of sound are different from those of light. The ear is a series of structures, each of which plays a part in the sense of hearing.

6.7.1 The Outer Ear

The pinna is the visible, external part of the ear that serves as a kind of concentrator, funnelling the sound waves from the outside into the structure of the ear. The pinna is also the entrance to the auditory canal (or ear canal), the short tunnel that runs down to the tympanic membrane, or eardrum. When sound waves hit the eardrum, they cause three tiny bones in the middle ear to vibrate.

6.7.2 The Middle Ear

The three tiny bones in the middle ear are known as the hammer (malleus), anvil (incus), and stirrup (stapes), each name stemming from the shape of the respective bone. The vibration of these three bones amplifies the vibrations from the eardrum. The stirrup, the last bone in the chain, causes a membrane covering the opening of the inner ear to vibrate.

6.7.3 The Inner Ear

This membrane is called the oval window, and its vibrations set off another chain reaction within the inner ear.

6.7.3.1 Cochlea

The inner ear is a snail-shaped structure called the cochlea, which is filled with fluid. When the oval window vibrates, it causes the fluid in the cochlea to vibrate. This fluid surrounds a membrane running through the middle of the cochlea called the basilar membrane.

6.7.3.2 Basilar Membrane and the Organ of Corti

The basilar membrane is the resting place of the organ of Corti, which contains the receptor cells for the sense of hearing. When the basilar membrane vibrates, it vibrates the organ of Corti, causing it to brush against a membrane above it. On the organ of Corti are special cells called hair cells, which are the receptors for sound. When these auditory receptors or hair cells are bent up against the other membrane, it causes them to send a neural message through the auditory nerve and into the brain, where the auditory cortex will interpret the sounds (the transformation of the vibrations of sound into neural messages is transduction). The louder the sound in the outside world, the stronger the vibrations that stimulate more of those hair cells—which the brain interprets as loudness.

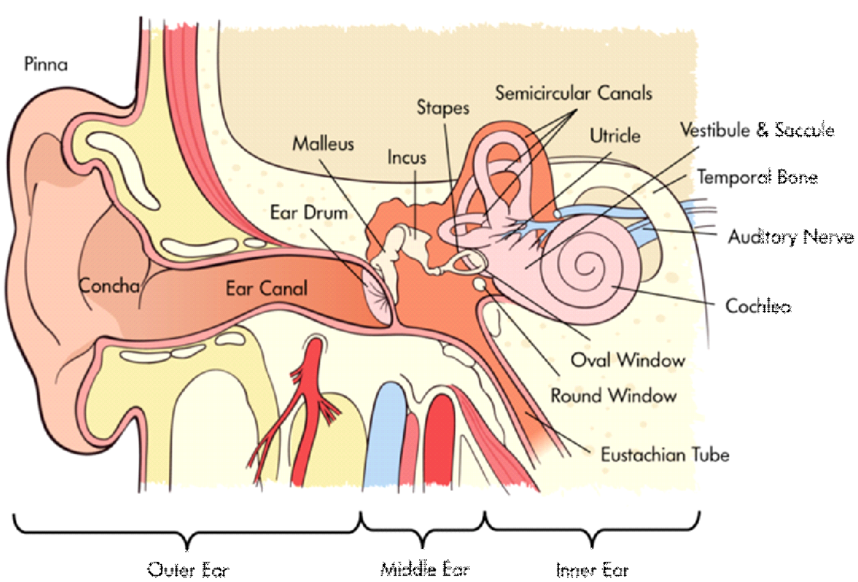

Figure 6.3

6.8 Chemical Senses

The sense of taste (taste in food, not taste in clothing or friends) and the sense of smell are very closely related. Have you ever noticed that when your nose is all stopped up, your sense of taste is affected, too? That's because the sense of taste is really a combination of taste and smell. Without the input from the nose, there are actually only four, and possibly five, kinds of taste sensors in the mouth.

6.8.1 Gustation

Taste buds are the common name for the taste receptor cells, special kinds of neurons found in the mouth that are responsible for the sense of taste, or gustation. Most taste buds are located on the tongue, but there are a few on the roof of the mouth, the cheeks, and under the tongue as well. The sensitivity for various tastes in people depends on how many taste buds they have; some people have only around 500, whereas others have 20 times that number. The latter are called "supertasters" and need far less seasoning in their food than those with fewer taste buds. The little bumps seen on the tongue are called papillae, and the taste buds line the walls of these papillae.

Each taste bud has about 20 receptors that are very similar to the receptor sites on receiving neurons at the synapse. In fact, the receptors on taste buds work exactly like receptor sites on neurons—they receive molecules of various substances that fit into the receptor like a key into a lock. Taste is often called a chemical sense because it works with the molecules of foods people eat in the same way the neural receptors work with neurotransmitters. When the molecules (dissolved in saliva) fit into the receptors, a signal is fired to the brain, which then interprets the taste sensation.

In general, the taste receptors has such a workout that they have to be replaced every 10 to 14 days. And when the tongue is burned, the damaged cells no longer work. As time goes on, those cells get replaced and the taste sense comes back.

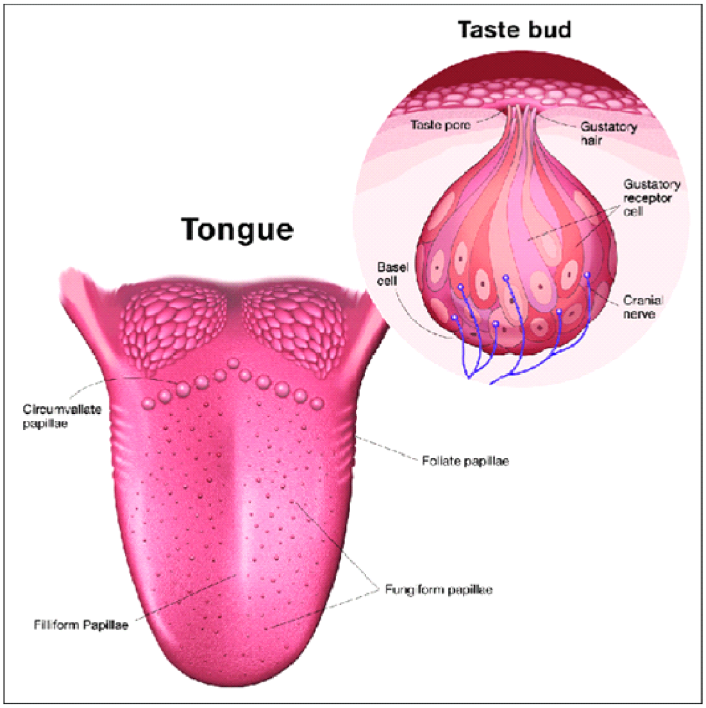

Figure 6.4

6.8.2 The Five Basic Tastes

In 1916 a German psychologist named Hans Henning proposed that there are four primary tastes: sweet, sour, salty, and bitter. Lindemann (1996) supported the idea that there is a fifth kind of taste receptor that detects a pleasant “brothy” taste associated with foods like chicken soup, tuna, kelp, cheese, and soy products, among others. Lindemann proposed that this fifth taste be called umami, a Japanese word first coined in 1908 to describe the taste. Dr. Ikeda identified that glutamate is the substance which helps in the sensation of umami. Glutamate is present in human breast milk and is the reason that the seasoning MSG—monosodium glutamate—adds a pleasant flavor to foods.

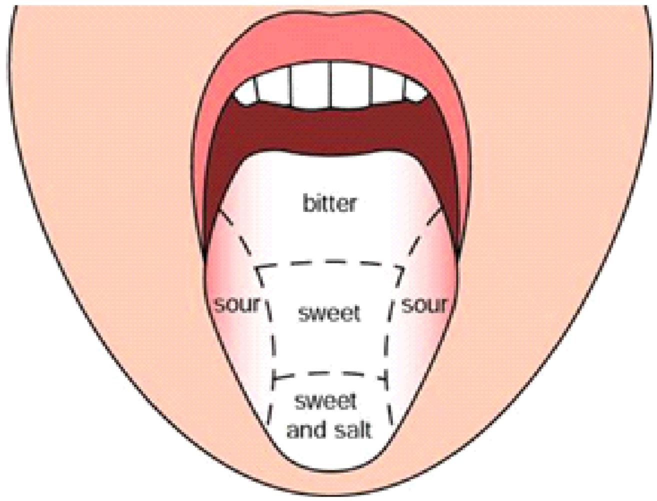

Figure 6.5

The five taste sensations work together, along with the sense of smell and the texture, temperature, and “heat” of foods, to produce thousands of taste sensations. Although researchers used to believe that certain tastes were located on certain places on the tongue (Figure 6.5), it is now known that all of the taste sensations are processed all over the tongue. Just as individuals and groups can vary on their food preferences, they can also vary on level of perceived sweetness. For example, obese individuals have been found to experience less sweetness than individuals who are not obese; foods that are both sweet and high in fat tend to be especially attractive to individuals who are obese.

6.9 The Sense of Scents: Olfaction

Like the sense of taste, the sense of smell is a chemical sense. The ability to smell odors is called olfaction, or the olfactory sense. The outer part of the nose serves the same purpose for odors that the pinna and ear canal serve for sounds: Both are merely ways to collect the sensory information and get it to the part of the body that will translate it into neural signals.

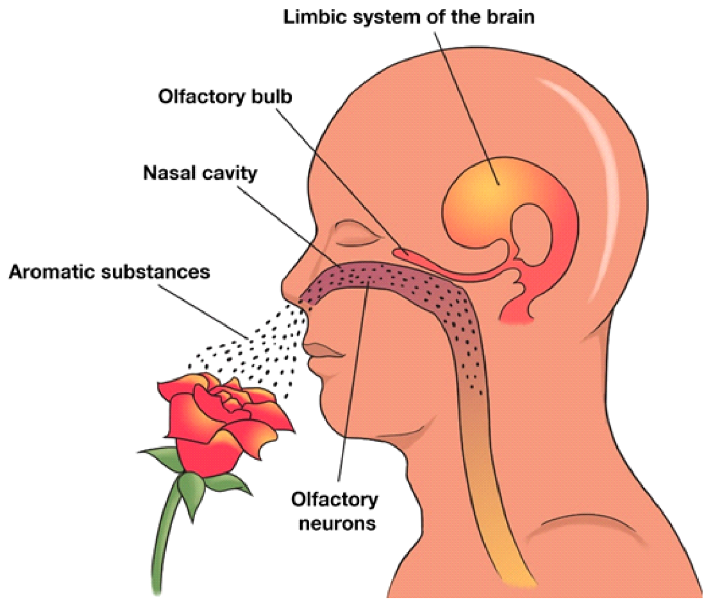

Figure 6.6

The part of the olfactory system that transduces odors—turns odors into signals the brain can understand—is located at the top of the nasal passages. This area of olfactory receptor cells is only about an inch square in each cavity yet contains about 10 million olfactory receptors.

6.9.1 Olfactory Receptor Cells

The olfactory receptor cells each have about a half dozen to a dozen little “hairs,” called cilia, that project into the cavity. Like taste buds, there are receptor sites on these hair cells that send signals to the brain when stimulated by the molecules of substances that are in the air moving past them. When a person is sniffing something, the sniffing serves to move molecules of whatever the person is trying to smell into the nose and into the nasal cavities.

Olfactory receptors are like taste buds in another way, too. Olfactory receptors also have to be replaced as they naturally die off, about every 5 to 8 weeks. Unlike the taste buds, there are way more than five types of olfactory receptors—in fact, there are at least 1,000 of them. Signals from the olfactory receptors in the nasal cavity do not follow the same path as the signals from all the other senses. Vision, hearing, taste, and touch all pass through the thalamus and then on to the area of the cortex that processes that particular sensory information. But the sense of smell has its own special place in the brain—the olfactory bulbs, which are actually part of the brain.

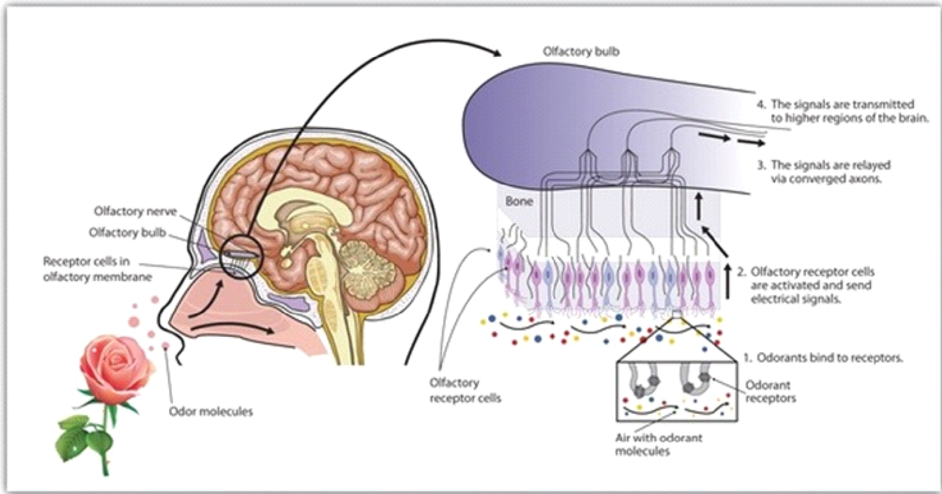

Figure 6.7

6.10 Somesthetic Senses

The sense of touch is really several sensations, originating in several different places in—and on—the body. It's really more accurate to refer to these as the body senses, or somesthetic senses. The first part of that word, soma, means "body,". The second part, esthetic, means "feeling," hence, the name. There are three somesthetic sense systems, the skin senses (having to do with touch, pressure, temperature, and pain), the kinesthetic sense (having to do with the location of body parts in relation to each other), and the vestibular senses (having to do with movement and body position).

6.10 Conclusion

The sense-organs were the necessary material basis of perception. The classic five senses are sight, smell, hearing, taste, and touch. The organs that do these things are the eyes, nose, ears, tongue, and skin. The sense organs -eyes, ears, tongue, skin, and nose - help to protect the body. The human sense organs contain receptors that relay information through sensory neurons to the appropriate places within the nervous system. Each sense organ contains different receptors.

6.11 SUMMARY

Sensation is the activation of receptors located in the eyes, ears, skin, nasal cavities, and tongue. Sensory receptors are specialized forms of neurons that are activated by different stimuli such as light and sound. A just noticeable difference is the point at which a stimulus is detectable half the time it is present. Weber's law of just noticeable differences states that the just noticeable difference between two stimuli is always a constant. Absolute thresholds are the smallest amount of energy needed for conscious detection of a stimulus at least half the time it is present. Subliminal stimuli are stimuli presented just below the level of conscious awareness. Habituation occurs when the brain ignores a constant stimulus. Sensory adaptation occurs when the sensory receptors stop responding to a constant stimulus.

Light enters the eye and is focused through the cornea, passes through the aqueous humor, and then through the hole in the iris muscle called the pupil. The lens also focuses the light on the retina, where it passes through ganglion and bipolar cells to stimulate the rods and cones. Sound has three aspects: pitch (frequency), loudness, and timbre (purity). Sound enters the ear through the visible outer structure, or pinna, and travels to the eardrum and then to the small bones of the middle ear. The bone called the stirrup rests on the oval window, causing the cochlea and basilar membrane to vibrate with sound.. The organ of Corti on the basilar membrane contains the auditory receptors, which send signals to the brain about sound qualities as they vibrate. Gustation is the sense of taste. Taste buds in the tongue receive molecules of substances, which fit into receptor sites. The five basic types of taste are sweet, sour, salty, bitter, and umami (brothy). Olfaction is the sense of smell. The olfactory receptors in the upper part of the nasal passages receive molecules of substances and create neural signals that then go to the olfactory bulbs under the frontal lobes.

6.12 KEY WORDS:

::Absolute threshold

The lowest level of stimulation that a person can consciously detect 50 percent of the time the stimulation is present.

::Blind spot

Area in the retina where the axons of the three layers of retinal cells exit the eye to form the optic nerve, insensitive to light.

::Cones

Visual sensory receptors found at the back of the retina, responsible for color vision and sharpness of vision.

::Gustation

The sensation of a taste

::Habituation

Tendency of the brain to stop attending to constant, unchanging information.

::Just noticeable difference (jnd or the difference threshold)

The smallest difference between two stimuli that is detectable 50 percent of the time.

::Kinesthetic sense

Sense of the location of body parts in relation to the ground and each other.

::Olfaction (olfactory sense)

The sensation of smell.

::Olfactory bulbs

Areas of the brain located just above the sinus cavity and just below the frontal lobes that receive information from the olfactory receptor cells.

::Rods

Visual sensory receptors found at the back of the retina, responsible for noncolor sensitivity to low levels of light

::Sensation

The process that occurs when special receptors in the sense organs are activated, allowing various forms of outside stimuli to become neural signals in the brain.

::Sensory adaptation

Tendency of sensory receptor cells to become less responsive to a stimulus that is unchanging.

::Skin senses

The sensations of touch, pressure, temperature, and pain

::Somesthetic senses

The body senses consisting of the skin senses, the kinesthetic sense, and the vestibular senses.

::Vestibular senses

The sensations of movement, balance, and body position.

::Visual accommodation

The change in the thickness of the lens as the eye focuses on objects that are far away or close.

6.13 CHECK YOUR PROGRESS

1. You find that you have to add 1 teaspoon of sugar to a cup of coffee that already has 5 teaspoons of sugar in it to notice the difference in sweetness. If you have a cup of coffee with 10 teaspoons of sugar in it, how many teaspoons would you have to add to notice the difference in sweetness at least half the time?

    a. 1

    b. 2

    c. 4

    d. 5

2. The process by which the brain stops attending to constant, unchanging information is called:

    a. adaptation

    b. sensation

    c. habituation

    d. accommodation

3. The thin membrane stretched over the opening to the inner ear is the __________.

   a. pinna

   b. oval window

   c. tympanic membrane

   d. cochlea

4. The sense of taste is closely related to the sense of __________.

   a. sight

   b. hearing

   c. smell

   d. touch

5. The "bumps" on the tongue that are visible to the eye are the __________.

   a. taste buds

   b. papillae

   c. taste receptors

   d. olfactory receptors.

6. Which of the following statements about olfactory receptors is TRUE?

   a. Olfactory receptors are replaced every 5 to 8 weeks.

   b. There are fewer than 50 types of olfactory receptors.

   c. Signals from the receptors go through the brain stem and then to the cortex.

   d. Olfactory receptors respond to pressure.

6.14 ANSWERS TO CHECK YOUR PROGRESS:

1. b

2. a

3. c

4. c

5. a

6. a

6.15 MODEL QUESTIONS:

1. Why are some sensations ignored?

2. Explain the different sensory modalities.

3. Brief out the structure of different sense organs.

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LESSON – 7

PROCESS OF SENSATION- VISUAL AND AUDITORY

INTRODUCTION

Information about the world has to have a way to get into the brain, where it can be used to determine actions and responses. The way into the brain is through the sensory organs and the process of sensation. The following section gives a brief history of how scientists have tried to “shed light” on the mystery of light and sound.

LEARNING OBJECTIVES

At the end of this unit you will be able to understand

- the general process by which sensation occurs in any sense modality
- the role of sensory receptors in sensory transduction.
- the physical basis of our sense of vision, and the significance of the amplitude, brightness and saturation of a light.
- the main properties of sound waves, explaining how they affect perceived pitch and loudness.

PLAN OF THE LESSON

7.1 Perceptual properties of light

7.2 Visual processing

7.3 Perception of color: Theories of color vision

7.4 Color blindness

7.5 The hearing sense: Perception of sound

7.6 Perceiving pitch

7.7 Types of hearing impairments

7.8 Conclusion

7.9 Summary

7.10 Key words

7.1 Perceptual properties of light

It was Albert Einstein who first proposed that light is actually tiny “packets” of waves. These “wave packets” are called photons and have specific wavelengths associated with them. When people experience the physical properties of light, they are not really aware of its dual, wavelike and particle-like, nature. With regard to its psychological properties, there are three aspects to our perception of light: brightness, color, and saturation.

Brightness is determined by the amplitude of the wave—how high or how low the wave actually is. The higher the wave, the brighter the light appears to be. Low waves are dimmer.

Color, or hue, is largely determined by the length of the wave. Long wavelengths (measured in nanometres) are found at the red end of the visible spectrum (the portion of the whole spectrum of light that is visible to the human eye), whereas shorter wavelengths are found at the blue end.

7.2 Visual Processing

Light entering the eyes can be separated into the left and right visual fields. Light from the right visual field falls on the left side of each eye’s retina; light from the left visual field falls on the right side of each retina. Light travels in a straight line through the cornea and lens; resulting in the image projected on the retina actually being upside down and reversed from left to right as compared to the visual fields.

The areas of the retina can be divided into halves, with the halves toward the temples of the head referred to as the temporal retinas and the halves toward the center, or nose, called the nasalretinas. The information from the left visual field (falling on the right side of each retina) goes directly to the right visual cortex, while the information from the right visual field (falling on the left side of each retina) goes directly to the left visual cortex .This is because the axons from the temporal halves of each retina project to the visual cortex on the same side of the brain while the axons from the nasal halves cross over to the visual cortex on the opposite side of the brain. The optic chiasm is the point of crossover.

The photoreceptors in the retina, the rods and cones are responsible for different aspects of vision. The rods (about 120 million of them in each eye) are found all over the retina except in the very centre, which contains only cones. Rods are sensitive to changes in brightness but not to changes in wavelength, so they see only in black and white and shades of grey. They can be very sensitive because many rods are connected to a single bipolar cell, so that if even only one rod is stimulated by a photon of light, the brain perceives the whole area of those rods as stimulated (because the brain is receiving the message from the single bipolar cell). But because the brain doesn't know exactly what part of the area (which rod) is actually sending the message, the visual acuity (sharpness) is quite low. That's why things seen in low levels of light, such as twilight or a dimly lit room, are fuzzy and greyish. Because rods are located on the periphery of the retina, they are also responsible for peripheral vision. Because rods work well in low levels of light, they are also the cells that allow theeyes to adapt to low light.

Dark adaptation occurs as the eye recovers its ability to see when going from a brightly lit state to a dark state. (The light-sensitive pigments that allow us to see are able to regenerate or "recharge" in the dark.) The brighter the light was, the longer it takes the rods to adapt to the new lower levels of light (Bartlett, 1965). This is why the bright headlights of an oncoming car can leave a person less able to see for a while after that car has passed. Fortunately, this is usually a temporary condition because the bright light was on so briefly and the rods readapt to the dark night relatively quickly.

Full dark adaptation, which occurs when going from more constant light to darkness such as turning out one's bedroom lights, takes about 30 minutes. As people get older this process takes longer, causing many older persons to be less able to see at night and in darkened rooms. This age-related change can cause night blindness, in which a person has difficulty seeing well enough to drive at night or get around in a darkened room or house.

Some research indicates that taking supplements such as vitamin A can reverse or relieve this symptom in some cases. When going from a darkened room to one that is brightly lit, the opposite process occurs. The cones have to adapt to the increased level of light, and they accomplish this light adaptation much more quickly than the rods adapt to darkness—it takes a few seconds at most. There are 6 million cones in each eye; of these, 50,000have a private line to the optic nerve (one bipolar cell for each cone). This means that the cones are the receptors for visual acuity. Cones are located all over the retina but are more concentrated at its very centre where there are no rods (the area called the fovea).

Cones also need a lot more light to function than the rods do, so cones work best in bright light, which is also when people see things most clearly. Cones are also sensitive to different wavelengths of light, so they are responsible for color vision.

7.3 Perception of color: Theories of color vision

Two theories of colors were originally proposed in the 1800s. The first is called the trichromatic ("three colors") theory. This theory was first proposed by Thomas Young in 1802 and later modified by Hermann vonHelmholtz in 1852.This theory proposed three types of cones: red cones, blue cones, and green cones, one for each of the three primary colors of light. Most people probably think that the primary colors are red, yellow, and blue, but these are the primary colors when talking about painting—not when talking about light.

In the trichromatic theory, different shades of colors correspond to different amounts of light received by each of these three types of cones. These cones then fire their message to the brain's vision centres. It is the combination of cones and the rate at which they are firing that determine the color that will be seen. For example, if the red and green cones are firing in response to a stimulus at fast enough rates, the color the person sees is yellow. If the red and blue cones are firing fast enough, the result is magenta. If the blue and green cones are firing fast enough, a kind of cyan color (blue-green) appears.

Brown and Wald (1964) identified three types of cones in the retina, each sensitive to a range of wavelengths, measured in nanometres (nm), and a peak sensitivity that roughly corresponds to three different colors (although hues/colors can vary depending on brightness and saturation). The peak wavelength of light the cones seem to be most sensitive to turns out to be just a little different from Young and von Helmholtz's original three corresponding colors: Short wavelength cones detect what we see as blue-violet (about 420 nm), medium wavelength cones detect what we see as green (about 530 nm), and long wavelength cones detect what we see as green-yellow (about 560 nm). Interestingly, none of the cones identified by Brown and Wald have a peak sensitivity to light where most of us see red (around 630 nm).

This indicates that, each cone responds to light across a range of wavelengths, and not just its wavelength of peak sensitivity. Depending on the intensity of the light, both the medium and long wavelength cones respond to light that appears red.

7.3.1 The after image

The trichromatic theory seem to be more than adequate to explain how people perceive color. But there's an interesting phenomenon that this theory cannot explain. If a person stares at a picture of the American flag for a little while—say, a minute—and then looks away to a blank white wall or sheet of paper, that person will see an afterimage of the flag.

Afterimages occur when a visual sensation persists for a brief time even after the original stimulus is removed. The phenomenon of the color afterimage is explained by the second theory of color perception, called the opponent-process theory (De Valois & De Valois, 1993;Hurvich& Jameson, 1957), based on an idea first suggested by Edwald Hering in1874 (Finger, 1994). In opponent-process theory, there are four primary colors: red, green, blue, and yellow. The colors are arranged in pairs, red with green and blue with yellow. If one member of a pair is strongly stimulated, the other member is inhibited and cannot be working—so there are no reddish-greens or bluish-yellows. So how can this kind of pairing cause a color afterimage? From the level of the bipolar and ganglion cells in the retina, all the way through the thalamus, and on to the visual cortical areas in the brain, some neurons (or groups of neurons) are stimulated by light from one part of the visual spectrum and inhibited by light from a different part of the spectrum. For example, let's say we have a red-green ganglion cell in the retina whose baseline activity is rather weak when we expose it to white light. However, the cell's activity is increased by red light, so we experience the color red. If we stimulate the cell with red light for a long enough period of time, the cell becomes fatigued. If we then swap out the red light with white light, the now-tired cell responds even less than the original baseline. Now we experience the color green, because green is associated with a decrease in the responsiveness of this cell.

Both theories play a part in color vision. Trichromatic theory can explain what is happening with the raw stimuli, the actual detection of various wavelengths of light. Opponent-process theory can explain after images and other aspects of visual perception that occur after the initial detection of light from our environment.

In addition to the retinal bipolar and ganglion cells, opponent-process cells are contained inside the thalamus in an area called the lateral geniculate nucleus (LGN). The LGN is part of the pathway that visual information takes to the occipital lobe. It is when the cones in the retina send signals through the retinal bipolar and ganglion cells that we see the red versus green pairings and blue versus yellow pairings. Together with the retinal cells, the cells in the LGN appear to be the ones responsible for opponent-processing of color vision and the afterimage effect.

7.4 Color blindness

There are two kinds of color blindness, when you can't tell red from green and when you can't tell blue from yellow. From the mention of red-green and yellow-blue color blindness, one might think that the opponent-process theory explains this problem. But in reality "color blindness" is caused by defective cones in the retina of the eye and as a more general term, color-deficient vision is more accurate, as most people with "color blindness" have two type of cones working and can see many colors.

There are really three kinds of color-deficient vision. In a very rare type, monochrome color blindness, people either have no cones or have cones that are not working at all. Essentially, if they have cones, they only have one type and, therefore, everything looks the same to the brain—shades of grey. The other types of color-deficient vision, or dichromatic vision, are caused by the same kind of problem—having one cone that does not work properly. Protanopia (red-green color deficiency) is due to the lack of functioning red cones and deuteranopia (another type of red-green color deficiency) results from the lack of functioning green cones. In both of these, the individual confuses reds and greens, seeing the world primarily in blues, yellows, and shades of gray. A lack of functioning blue cones is much less common and called tritanopia (blue-yellow color deficiency). These individuals see the world primarily in reds, greens, and shades of gray.

Color-deficient vision involving one set of cones is inherited in a pattern known assex-linked inheritance. The gene for color-deficient vision is recessive. To inherit a recessive trait, you normally need two of the genes, one from each parent. But the gene for color-deficient vision is attached to a particular chromosome (a package of genes) that helps to determine the sexof a person. Men have one X chromosome and one smaller Y chromosome (named for their shapes), whereas women have two X chromosomes. The smaller Y has fewer genes than the larger X, and one of the genes missing is the one that would suppress the gene for color-deficient vision. For a woman to have color-deficient vision, she must inherit two recessive genes, one from each parent, but a man only needs to inherit one recessive gene—the one passed on to him on his mother's X chromosome. His odds are greater; therefore, more males than females have color-deficient vision.

7.5 The hearing sense: Perception of sound

The properties of sound are indeed similar to those of light, as both senses rely on waves. But the similarity ends there, as the physical properties of sound are different from those of light.

Sound waves do not come in little packets the way light comes in photons. Sound waves are simply the vibrations of the molecules of air that surround us. Sound waves do have the same properties of light waves though—wavelength, amplitude, and purity. Wavelengths are interpreted by the brain as the frequency or pitch (high, medium, or low). Amplitude is interpreted as volume, how soft or loud a sound is. Finally, what would correspond to saturation or purity in light is called timbre in sound, a richness in the tone of the sound. And just as people rarely see pure colors in the world around us, they also seldom hear pure sounds. Just as a person's vision is limited by the visible spectrum of light, a person is also limited in the range of frequencies he or she can hear. Frequency is measured in cycles (waves) per second, or hertz (Hz). Human limits are between 20 and 20,000 Hz, with the most sensitivity from about 2000 to 4000 Hz, very important for conversational speech.

7.6 Perceiving pitch

Pitch refers to how high or low a sound is. For example, the bass tones in the music pounding through the wall of your apartment from the neighbors next door is a low pitch, whereas the scream of a 2-year-old child is a very high pitch. There are three primary theories about how the brain receives information about pitch. They are the place theory, the frequency Theory and Volley principle. The oldest of the three theories is the place theory.

7.6.1 Place Theory

It is based on an idea proposed in 1863by Hermann von Helmholtz and elaborated on and modified by Georg von Békésy in 1928. In this theory, the pitch a person hears depends on where the hair cells that are stimulated are located on the organ of Corti. For example, if the person is hearing a high-pitched sound, all of the hair cells near the oval window will be stimulated, but if the sound is low pitched, all of the hair cells that are stimulated will be located farther away on the organ of Corti.

7.6.2 Frequency theory

Frequency theory, developed by Ernest Rutherford in 1886, states that pitch is related to how fast the basilar membrane vibrates. The faster this membrane vibrates, the higher the pitch; the slower it vibrates, the lower the pitch. (In this theory, all of the auditory neurons would be firing at the same time.)

Both the theories are right upto a point. For place-theory research to be accurate, the basilar membrane has to vibrate unevenly—which it does when the frequency of the sound is above 1000 Hz. For the frequency theory to be correct, the neurons associated with the hair cells would have to fire as fast as the basilar membrane vibrates. This only works up to 1000 Hz, because neurons don't appear to fire at exactly the same time and rate when frequencies are faster than 1000 times per second. The frequency theory works for low pitches, and place theory works for moderate to high pitches.

7.6.3 Volley Principle

There is a third theory, developed by Ernest Wever and Charles Bray, called the volley principle,which appears to account for pitches from about 400 Hz up to about 4000. In this explanation, groups of auditory neurons take turns firing in a process called volleying. If a person hears a tone of about 3000 Hz, it means that three groups of neurons have taken turns sending the message to the brain—the first group for the first 1000 Hz, the second group for the next 1000 Hz, and so on.

7.7 Types of hearing impairments

Hearing impairment is the term used to refer to difficulties in hearing. A person can be partially hearing impaired or totally hearing impaired, and the treatment for hearingloss will vary according to the reason for the impairment.

7.7.1 Conduction hearing impairment

Conduction hearing impairment means that sound vibrations cannot be passed from the eardrum to the cochlea. The cause might be a damaged eardrum or damage to the bones of the middle ear (usually from an infection). In this kind of impairment, hearing aids may be of some use in restoring hearing.

7.7.2 Nerve hearing impairment

In nerve hearing impairment, the problem lies either in the inner ear or in the auditory pathways and cortical areas of the brain. Normal aging causes loss of hair cells in the cochlea, and exposure to loud noises can damage hair cells. Tinnitus is a fancy word for an extremely annoying ringing in one' sears, and it can also be caused by infections or loud noises—including loud music in headphones, so you might want to turn down that music player! Because the damage is to the nerves or the brain, nerve hearing impairment cannot be helped with ordinary hearing aids, which are basically sound amplifiers.

A technique for restoring some hearing to those with nerve hearing impairment makes use of an electronic device called a cochlear implant. This device sends signals from a microphone worn behind the ear to a sound processor worn on the belt or in a pocket, which then translates those signals into electrical stimuli that are sent to a series of electrodes implanted directly into the cochlea, allowing transduction to take place and stimulating the auditory nerve. The brain then processes the electrode information as sound.

7.8 Conclusion

Knowledge of our internal and external world becomes possible with the help of senses. Vision and audition are the two most widely used senses. Rods and cones are the receptors for vision. Rods function in low intensities of light, whereas cones function at high intensities of light. They are responsible for achromatic and chromatic vision, respectively. Light and dark adaptations are two interesting phenomena of the visual system. Hue, saturation and brightness are the basic dimensions of colour. Sound serves as stimulus for auditory sensations. Loudness, pitch, and timbre are the properties of sound. Organ of corti located in the basilar membrane is the chief organ of hearing. Difficulties in hearing occurs when there is damage in middle ear or inner ear.

7.9 Summary

Brightness corresponds to the amplitude of light waves, whereas color corresponds to the length of the light waves. Rods detect changes in brightness but do not see color and function best in low levels of light. They do not respond to different colors and are found everywhere in the retina except the centre, or fovea. Cones are sensitive to colors and work best in bright light. They are responsible for the sharpness of visual information and are found in the fovea.

Trichromatic theory of color perception assumes three types of cones: red, green, and blue. All colors would be perceived as combinations of these three. Opponent-process theory of color perception assumes four primary colors of red, green, blue, and yellow. Colors are arranged in pairs, and when one member of a pair is activated, the other is not. Color blindness is a total lack of color perception whereas color-deficient vision refers to color perception that is limited primarily to yellows and blues or reds and greens only.

Sound has three aspects: pitch (frequency), loudness, and timbre (purity). Place theory states that the location of the hair cells on the organ of Corti correspond to different pitches of sound. This can explain pitch above 1000 Hz. Frequency theory states that the speed with which the basilar membrane vibrates corresponds to different pitches of sound. This can explain pitch below 1000 Hz. The volley principle states that neurons take turns firing for sounds above 400 Hz and below 4000 Hz. Conduction hearing impairment is caused by damage to the outer or middle ear structures, whereas nerve hearing impairment is caused by damage to the inner ear or auditory pathways in the brain.

7.10 Key words

:: After images

Images that occur when a visual sensation persists for a brief time even after the original stimulus is removed

::Dark adaptation

The recovery of the eye's sensitivity to visual stimuli in darkness after exposure to bright lights.

::Frequency theory

theory of pitch that states that pitch is related to the speed of vibrations in the basilar membrane.

::Hertz (Hz)

Cycles or waves per second, a measurement of frequency.

::Light adaptation

The recovery of the eye's sensitivity to visual stimuli in light after exposure to darkness.

::Opponent-process theory

Theory of color vision that proposes visual neurons (or groups of neurons) are stimulated by light of one color and inhibited by light of another color.

::Pitch

Psychological experience of sound that corresponds to the frequency of the sound waves; higher frequencies are perceived as higher pitches.

::Place theory

Theory of pitch that states that different pitches are experienced by the stimulation of hair cells in different locations on the organ of Corti.

::Trichromatic theory

Theory of color vision that proposes three types of cones: red, blue, and green

::Volley principle

Theory of pitch that states that frequencies from about 400 Hz to 4000 Hz cause the hair cells (auditory neurons) to fire in a volley pattern, or take turns in firing.

7.11 Check Your Progress:

1. Which of the following terms refers to the perceived effect of the amplitude of light waves?
   a. color
   b. brightness
   c. saturation
   d. hue

2. If you wanted to locate a dimly lit star better at night, what should you do?
   a. Look directly at it because the cones will focus better at night.
   b. Look off to the side, using the cones in the periphery of the retina.
   c. Look directly at it because the rods can see sharply at night.
   d. Look off to the side, using the rods in the periphery of the retina.

3. Which theory of color vision best accounts for after images?
   a. trichromatic theory
   b. opponent-process theory
   c. both a and b
   d. neither a nor b

4. Which statement about color-deficient vision is TRUE?
   a. There are more men with color-deficient vision than women.
   b. All people with color-deficient vision see only in black and white.
   c. Some people with color-deficient vision see only in blue.
   d. Some people with color-deficient vision see only in blue and red.

5. Which of the following properties of sound would be the most similar to the color or hue of light?
   a. pitch
   b. loudness
   c. purity
   d timbre

6. The ___________ theory best explains how we hear sounds above 4000 Hz.
   a. place
   b. frequency
   c. volley
   d. adaptive

7. If the bones of the middle ear begin to deteriorate, you will develop ___________ hearing impairment.
   a. nerve
   b. stimulation

c. brain pathway

d. conduction

7.12 Answers to check your progress

1. b
2. d
3. c
4. a
5. a
6. c
7. d

7.13 Model Questions:

1. Explain the processing of light.
2. What are the different theories of vision?
3. What is meant by light and dark adaptation? How do they take place?
4. What is colour vision and what are the dimensions of colour?
5. How does auditory sensation take place?

LESSON 8

SENSORY PROCESSES- CHEMICAL, GUSTATORY AND TACTUAL

INTRODUCTION

We have five senses, but only two that go beyond the boundaries of ourselves. Know what smell is? . . . It's made up of the molecules of what you're smelling. We will consider olfaction first and then taste. And also to act purposefully and gracefully, we need constant information about the position of our limbs and other body parts in relation to each other and to objects in the environment.

OBJECTIVES OF THE LESSON

At the end of this lesson you will be able to understand

- the process of chemical senses
- what are somesthetic senses
- the senses of touch, pressure and temperature
- the process of pain

PLAN OF THE LESSON

8.1 Chemical Senses - Smell and Taste

The physical stimulus for our sense of smell is gas. However, to be detected the gas must be soluble in liquid. Even the smell of a solid (such as your desk or your hand or any other nearby "solid" object) results from minute gaseous emissions from the object. Efforts to identify a small number of basic smells from which others might be composed haven't been successful. Three different theories of "basic" psychological smells agree only on putrid, burnt, and fruity (or musky). There is no universally accepted list of basic psychological smells. Whereas the receptors for smell react to substances in gaseous form, the receptors for taste react to substances in liquid form. It is easier to identify tastes than smells.

8.1.1 The Nose: Smell Receptor

The receptor site for the sense of smell is located on the roof of the nasal cavity. If a new smell in the environment is detected, the normal response is to "sniff." The differences in "sniffs" from one person to another make it very difficult to state definitely how much air has been swirled past the sensing surface. This, and the remote location of the olfactory epithelium, cause problems in studying the sense of smell.

If you hold your nose and breathe in gently through your mouth, even in a room where there is a pronounced odor, you will not detect it unless air spills into your nasal cavity from the rear. In addition, if you breathe normally and quietly through your nose, you will very quickly adapt to the smells in your environment.

8.2 Operation of the Chemical Senses

There are two aspects of the sense of smell that are remarkable. One is the extreme sensitivity of the sense. You can detect as little as 7 parts per 10 billion of some musky aromas. Second, the sense of smell is also remarkable for its ability to detect specific but very small differences in chemical structure. Any theory of smell must be able to account for both of these abilities.

One of the most successful explanations of smell has come to be known as the lock-and-key-theory. It proposes that the shape, not the chemical structure, of gaseous molecules is important in detecting different odors. Much work remains to determine how different-shaped molecules can influence the sense of smell.

Olfaction (smell) is extremely important in the lives of many species because it is often their primary window to the environment. One important contrast between humans and other species is that many animals are macrosmatic (having a keen sense of smell that is important to their survival), whereas humans are microsmatic (having a less keen sense of smell that is not crucial to their survival). Smell is also extremely important in sexual reproduction because it triggers mating behavior in many species.

Although olfaction may not be as central to our sensory experience as vision, hearing, or touch, some of its effects may be occurring without our awareness. But perhaps the most convincing argument for the importance of smell to humans comes from those who suffer from anosmia, the loss of the ability to smell as a result of injury or infection. People suffering from anosmia describe the great void created by their inability to taste many foods because of the close connection between smell and flavour. Olfaction is more important in our lives than most of us realize, and, although it may not be essential to our survival, life is often enhanced by our ability to smell and becomes a little more dangerous if we lose the olfactory warning system that alerts us to spoiled food, leaking gas, or smoke from a fire.

8.2.1 Detecting Odors

Our sense of smell enables us to detect extremely low concentrations of some odorants. The detection threshold for odors is the lowest concentration at which an odorant can be detected. It is notable that there is a very large range of thresholds. T-butyl mercepatan, the odorant that is added to natural gas, can be detected in very small concentrations of less than 1 part per billion in air. In contrast, to detect the vapors of acetone (the main component of nail polish remover), the concentration must be 15,000 parts per billion, and for the vapor of methanol, the concentration must be 141,000 parts per billion.

Another aspect of odor detection is the difference threshold—the smallest difference in the concentration of two odors that can be detected. Measurements of the difference threshold highlight one of the most important problems in olfactory research—the control of concentrations in stimulus presentations. For example, when William Cain (1977) carefully measured the difference threshold by placing two odorants of different concentrations on absorbent cotton balls and asked participants to judge which was more intense, he found that the difference threshold averaged 19 percent. However, when Cain analysed the stimuli he had presented on the cotton balls, he found that stimuli that were supposed to have the same concentration actually varied considerably. This variation was apparently caused by differences in the airflow pattern through the cotton in different samples. To deal with this problem, Cain remeasured the difference threshold using a device called an olfactometer, which presents olfactory stimuli with much greater precision than cotton balls. Using this more precise method of presenting of stimulus, Cain found that the threshold dropped to 11 percent.

8.2.2 Identifying Odors

When odorant concentrations are near threshold, so a person can just detect the presence of an odor, the person usually cannot sense the quality of the odor—whether it is “floral” or “pepper minty” or “rancid.” The concentration of an odorant has to be increased by as much as a factor of 3 above the threshold concentration before the person can recognize an odor’s quality. The concentration at which quality can be recognized is called the recognition threshold. One of the more intriguing facts about odors is that even though humans can discriminate between as many as 100,000 different odors (Firestein, 2001), they often find it difficult to accurately identify specific odors. For example, when people are presented with the odors of familiar substances such as mint, bananas, and motor oil, they can easily tell the difference between them. However, when they are asked to identify the substance associated with the odor, they are successful only about half the time.

One of the amazing things about odor identification is that knowing the correct label for the odor actually seems to transform our perception into that odor. Cain (1980) gives the example of an object initially identified as “fishy goaty oily.” When the experimenter told the person that the fishy-goat y-oily smell actually came from leather, the smell was then transformed into that of leather.

8.2.3 The Olfactory Mucosa

Part of the olfactory mucosa (OM) is a dime-sized region located high in the nasal cavity that contains the receptors for smell. The mucosa is located on the roof of the nasal cavity and just below the olfactory bulb. Odorant molecules are carried into the nose in an air stream, which brings these molecules into contact with the mucosa.

8.2.4 Olfactory Receptor Neurons

Just as the rod and cone receptors in the retina contain molecules called visual pigments that are sensitive to light, olfactory receptor neurons (ORNs) in the mucosa are dotted with molecules called olfactory receptors that are sensitive to chemical odorants. Other parallels between visual pigments and olfactory receptors are that they are both proteins that cross the membrane of the receptor neurons (rods and cones for vision; ORNs for olfaction) seven times, and they are both sensitive to a specific range of stimuli. Each type of visual pigment is sensitive to a band of wavelengths in a particular region of the visible spectrum, and each type of olfactory receptor is sensitive to a narrow range of odorants.

An important difference between the visual system and the olfactory system is that while there are only four different types of visual pigments (one rod pigment and three cone pigments), there are 350 different types of olfactory receptors, each sensitive to a particular group of odorants. The large number of olfactory receptors is important because it is one reason we can identify 100,000 or more different odors, but this large number of receptor types increases the challenges in understanding how olfaction works. One thing that makes things slightly simpler is another parallel with vision: Just as a particular rod or cone receptor contains only one type of visual pigment, a particular olfactory receptor neuron (ORN) contains only one type of olfactory receptor.

8.2.5 Activation of the Olfactory Bulb

Activation of receptors in the mucosa causes electrical signals in the ORNs that are distributed across the mucosa. These ORNs send signals to structures called glomeruli in the olfactory bulb. All of the 10,000 ORNs of a particular type send their signals to just one or two glomeruli. Each glomerulus therefore collects information about the firing of a particular type of ORN. The functional group associated with a particular type of compound (COOH for the acids; OH for the alcohols) determines the general area of the olfactory bulb that is activated, and the compound's chain length determines the position within each area.

8.2.6 The Biology of Olfaction

Biologically, the sense of smell, or olfaction, begins with chemical events in the nose. There, odors (in the form of airborne chemical molecules) interact with receptor proteins associated with specialized nerve cells. These cells, incidentally, are the body's only nerve cells that come in direct contact with the outside environment. Through the receptors they reach olfactory bulb.

From there, our sensations of smell are passed on to many other parts of the brain. Unlike all the other senses, smell signals are not relayed through the thalamus, suggesting that smell has very ancient evolutionary roots.

8.2.7 The Psychology of Smell

Olfaction has an intimate connection with both emotion and memory. This may explain why the olfactory bulbs lie very close to, and communicate directly with, structures in the limbic system and temporal lobes that are associated with emotion and memory. Therefore, it is not surprising that both psychologists and writers have noticed that certain smells can evoke emotion-laden memories, sometimes of otherwise-forgotten events. If you think about it for a moment, you can probably recall a vivid memory “image” of the aroma associated with a favorite food—perhaps fresh bread or a spicy dish—from your childhood.

8.3 Gustation

We will now move from olfaction, which detects molecules that enter the nose in gaseous form, to taste, which detects molecules that enter the mouth in solid or liquid form, usually as components of the foods we eat.

8.4 Functions of Taste

The taste and smell are thought of as “gatekeepers” that help us determine which substances we should consume and which we should avoid. This is especially true for taste because we often use taste to choose which foods to eat and which to avoid. Taste accomplishes its gatekeeper function by the connection between taste quality and a substance’s effect. Thus, sweetness is often associated with compounds that have nutritive or caloric value and that are, therefore, important for sustaining life. Sweet compounds cause an automatic acceptance response and also trigger anticipatory metabolic responses that prepares the gastrointestinal system for processing these substances. Bitter compounds have the opposite effect—they trigger automatic rejection responses to help the organism avoid harmful substances. Examples of harmful substances that taste bitter are the poisons strychnine, arsenic, and cyanide.

Salty tastes often indicate the presence of sodium. When people are deprived of sodium or lose a great deal of sodium through sweating, they will often seek out foods that taste salty in order to replenish the salt their body needs. People can, however, learn to modify their responses to certain tastes, as when they develop a taste for foods they may have initially found unappealing.

8.4.1 Basic Taste Qualities

When dealing with the problem of describing taste quality, we are in a much better position than we were for olfaction. The sense of taste (taste in food, not taste in clothing or friends) and the sense of smell are very closely related. Have you ever noticed that when your nose is all stopped up, your sense of taste is affected, too? That's because the sense of taste is really a combination of taste and smell. Without the input from the nose, there are actually only four, and possibly five, kinds of taste sensors in the mouth: salty, sour, sweet, bitter, and umami (which has been described as meaty, brothy, or savory, and is often associated with the flavor-enhancing properties of MSG, monosodium glutamate).

Early research that supported the idea of basic tastes showed that people can describe most of their taste experiences on the basis of the four basic taste qualities (this research was done before umami became the fifth basic taste). In one study, Donald McBurney (1969) presented taste solutions to participants and asked them to make magnitude estimates of the intensity of each of the four taste qualities for each solution. He found that some substances have a predominant taste and that other substances result in combinations of the four tastes. For example, sodium chloride (salty), hydrochloric acid (sour), sucrose (sweet), and quinine (bitter) are compounds that come the closest to having only one of the four basic tastes, but the compound potassium chloride (KCl) has substantial salty and bitter components. Similarly, sodium nitrate (NaNO3) results in a taste consisting of a combination of salty, sour, and bitter. Results such of these have led most researchers to accept the idea of basic tastes.

8.5 Processing of taste

One of the central questions in taste research has been the identification of the physiological code for taste quality. The process of tasting begins with the tongue, when receptors are stimulated by taste stimuli. In fact, the receptors on taste buds work exactly like receptor sites on neurons—they receive molecules of various substances that fit into the receptor like a key into a lock. The surface of the tongue contains many ridges and valleys caused by the presence of structures called papillae, which fall into four categories:

(1) filiform papillae, which are shaped like cones and are found over the entire surface of the tongue, giving it its rough appearance;

(2) fungiform papillae, which are shaped like mushrooms and are found at the tip and sides of the tongue;

(3) foliate papillae, which are a series of folds along the back of the tongue on the sides; and

(4) circumvilliate papillae, which are shaped like flat mounds surrounded by a trench and are found at the back of the tongue.

All of the papillae except the filiform papillae contain taste buds, and the whole tongue contains about 10,000 taste buds. Because the filiform papillae contain no taste buds, stimulation of the central part of the tongue, which contains only these papillae, causes no taste sensations. However, stimulation of the back or perimeter of the tongue results in a broad range of taste sensations.

Each taste bud contains 50–100 taste cells, which have tips that protrude into the taste pore. Transduction occurs when chemicals contact receptor sites located on the tips of these taste cells. Electrical signals generated in the taste cells are transmitted from the tongue in a number of different nerves: (1) the chorda tympani nerve (from taste cells on the front and sides of the tongue); (2) the glossopharyngeal nerve (from the back of the tongue); (3) the vagus nerve (from the mouth and throat); and (4) the superficial petronasal nerve (from the soft palette—the top of the mouth).

The fibres from the tongue, mouth, and throat make connections in the brain stem in the nucleus of the solitary tract, and from there, signals travel to the thalamus and then to two areas in the frontal lobe—the insula and the frontal operculum cortex—that are partially hidden behind the temporal lobe. In addition, fibres serving the taste system also reach the orbitofrontal cortex (OFC), which also receives olfactory signals.

8.5.1 Developmental Changes in Taste

Infants have heightened taste sensitivity, which is why babies universally cringe at the bitter taste of lemon. This super sensitivity, however, decreases with age. As a result, many elderly people complain that food has los t its taste—which really means that they have lost much of their sensory ability to detect differences in the taste and smell of food. Compounding this effect, taste receptors can be easily damaged by alcohol, smoke, acids, or hot foods. Fortunately, we frequently replace our gustatory receptors—as we do our smell receptors.

Because of this constant renewal, the taste system boasts the most resistance to permanent damage of all our senses, and a total loss of taste is extremely rare.

8.5.2 Supertasters

Individuals of any age vary in their sensitivity to taste sensations, a function of the density of papillae on the tongue. Those with the most taste buds are supertasters who live in a "neon" taste world relative to the rest of us—which accounts for their distaste for certain foods, such as broccoli or "diet" drinks, in which they detect a disturbingly bitter flavor. Such differences also speak to the problem of whether different people sense the world in the same way.

Bartoshuk's research suggests that, to the extent that the sense receptors exhibit some variation from one person to another, so does our sensory experience of the world. This variability is not so bizarre as to make one person's sensation of sweet the same as another person's sensation of sour. Rather, the variations observed involve simply the intensity of taste sensations, such as the bitter detected by supertasters.

Taste researchers have detected differences in taste preferences between supertasters and those with normal taste sensations. In particular, supertasters more often report disliking foods that they find too sweet or too fatty. Researchers have observed that super tasters, on the average, weigh less than their non super tasting counterparts.

8.6 Somesthetic Senses

So far, vision, hearing, taste, and smell senses are covered. That leaves touch. What is thought of as the sense of touch is really several sensations, originating in several different places in—and on—the body. These senses are referred as the body senses, or somesthetic senses. The first part of that word, soma, means "body,". The second part, esthetic, means "feeling," hence, the name. There are three somesthetic sense systems, the skin senses (having to do with touch, pressure, temperature, and pain), the kinesthetic sense (having to do with the location of body parts in relation to each other), and the vestibular senses (having to do with movement and body position).

8.7 Sense of touch, pressure and temperature

Skin is an organ. Its purposes include more than simply keeping bodily fluids in and germs out; skin also receives and transmits information from the outside world to the central nervous system (specifically, to the somatosensory cortex). Information about light touch, deeper pressure, hot, cold, and even pain is collected by special receptors in the skin's layers.

8.7.1 Types of receptors in the skin

There are about half a dozen different receptors in the layers of the skin. Some of them will respond to only one kind of sensation. For example, the Pacinian corpuscles are just beneath the skin and respond to changes in pressure. There are nerve endings that wrap around the ends of the hair follicles which are sensitive to both pain and touch. There are free nerve endings just beneath the uppermost layer of the skin that respond to changes in temperature and to pressure—and to pain. There are pain nerve fibres in the internal organs as well as receptors for pressure. There are actually different types of pain. There are receptors that detect pain (and pressure) in the organs, a type of pain called visceral pain.

Pain sensations in the skin, muscles, tendons, and joints are carried on large nerve fibres and are called somatic pain. Somatic pain is the body's warning system that something is being, or is about to be, damaged and tends to be sharp and fast. Another type of somatic pain is carried on small nerve fibres and is slower and more of a general ache. This somatic pain acts as a kind of reminder system, keeping people from further injury by reminding them that the body has already been damaged. For example, if you hit your thumb with a hammer, the immediate pain sensation is of the first kind—sharp, fast, and bright. But later the bruised tissue simply aches, letting you know to take it easy on that thumb.

People may not like pain, but its function as a warning system is vitally important. There are people who are born without the ability to feel pain, rare conditions called congenital analgesia and congenital insensitivity to pain with anhidrosis (CIPA). Children with these disorders cannot feel pain when they cut or scrape themselves, leading to an increased risk of infection when the cut goes untreated. They fear nothing—which can be a horrifying trial for the parents and teachers of such a child. These disorders affect the neural pathways that carry pain, heat, and cold sensations. (Those with CIPA have an additional disruption in the body's heat–cold sensing perspiration system [anhidrosis], so that the person is unable to cool off the body by sweating.)

A condition called phantom limb pain occurs when a person who has had an arm or leg removed sometimes "feels" pain in the missing limb. As many as 50 to 80 percent of people who have had amputations experience various sensations: burning, shooting pains, or pins-and-needles sensations where the amputated limb used to be. Once believed to be a psychological problem, some now believe that it is caused by the traumatic injury to the nerves during amputation.

8.8 Processing of Pain

If you have severe pain, nothing else matters. A wound or a toothache can dominate all other sensations. Yet, pain is also part of your body's adaptive mechanism that makes you respond to conditions that threaten damage to your body. Unlike other sensations, pain can arise from intense stimulation of various kinds, such as a very loud sound, heavy pressure, a pinprick, or an extremely bright light. But pain is not merely the result of stimulation. It is also affected by our moods and expectations.

8.8.1 Pain Receptors

In the skin, several types of specialized nerve cells, called nociceptors, sense painful stimuli and send their unpleasant messages to the central nervous system. Some nociceptors are most sensitive to heat, while others respond mainly to pressure, chemical trauma, or other tissue injury. There are even specialized nociceptors for the sensation of itching—itself a type of pain.

8.8.2 Pain in the Brain

Even though they may seem emanate from far-flung parts of the body, we actually feel painful sensations in the brain. There two distinct regions have primary roles in processing incoming pain messages. One, involving a pathway terminating in the parietal lobe, registers the location, intensity, and the sharpness or dullness of pain. The other, a group of structures deep in the frontal cortex and in the limbic system, registers just how unpleasant the painful sensation is. People with damage to this second region may notice a painful stimulus but report that it does not feel unpleasant.

8.8.3 Phantom Limbs

One intriguing puzzle about pain concerns the mysterious sensations often experienced by people who have lost an arm or leg—a condition known as a phantom limb. In such cases, the amputee feels sensations—sometimes quite painful ones—that seem to come from the missing body part. The phantom limb sensations do not originate in damaged nerves in the sensory pathways. Nor are they purely imaginary. Rather, they arise in the brain itself. It is the result of the brain generating sensation when none comes from the missing limb. The odd phenomenon of phantom limbs teaches that understanding pain requires understanding not only painful sensations but also mechanisms in the brain that both process and inhibit pain.

8.8.4 The Gate-Control Theory

No one has yet developed a theory that explains everything about pain, but Melzack and Wall's (1965, 1983) gate-control theory explains a lot. It explains why pain can sometimes be blocked or facilitated "top-down" by our mental state. The "gate" itself involves special interneurons that, when inhibited, "open" the pain pathway running up the spinal cord toward the brain, by releasing a substance called P. Closing the gate interferes with the transmission of pain messages in the spinal pathway.

Messages from non pain nerve fibres, such as those involved in touch, can inhibit pain transmission. This explains why you vigorously shake your hand when you hit your finger with a hammer. Just as important, messages from the brain can also close the gate. This is how opiate drugs, such as morphine, work—by initiating a cascade of inhibitory messages that travel downward to block incoming pain messages. The gate on the pain pathway can also be opened and closed by top-down psychological processes, such as hypnosis or the distraction of important events.

8.8.5 Dealing with Pain

People with congenital insensitivity to pain do not feel what is hurting them, and their bodies often become scarred and their limbs deformed from injuries they could have avoided if their brains were able to warn them of danger. Because of their failure to notice and respond to tissue-damaging stimuli, these people tend to die young.

In general, pain serves as an essential defence signal: It warns us of potential harm, and it helps us to survive in hostile environments and to get treatment for sickness and injury. Sometimes, however, chronic pain seems to be a disease in itself, with neurons in the pain pathways becoming hypersensitive, amplifying normal sensory stimulation into pain messages. Research also suggests that chronic pain may, at least sometimes, arise from genes that get "turned on" in nerve-damaged tissue

8.8.6 Analgesics

Analgesic drugs, ranging from over-the-counter remedies such as aspirin and ibuprofen to prescription narcotics such as morphine, are widely used and effective. These act in a variety of ways. Morphine, suppresses pain messages in the spinal cord and the brain; aspirin interferes with a chemical signal produced by damaged tissue.

Those using pain-killing drugs should be aware of unwanted side effects, such as digestive tract or liver damage and even addiction. But studies have shown that if you must use narcotics to control severe pain, the possibility of your becoming addicted is far less than it would be if you were using narcotics recreationally.

8.8.7 Psychological Techniques for Pain Control

Many people can also learn to control pain by psychological techniques, such as hypnosis, relaxation, and thought-distraction procedures. For instance, a child receiving a shot at the doctor's office might be asked to take a series of deep breaths and look away. Pain can also be modified by placebos, mock drugs made to appear as real drugs. For example, a placebo may be an injection of mild saline solution (salt water) or a pill made of sugar.

Such fake drugs are routinely given to a control group in tests of new pain drugs. Their effectiveness, of course, involves the people's belief that they are getting real medicine. It is important to note, however, that the brain's response to a placebo is much the same as that of pain-relieving drugs: closing the spinal gate. Because this placebo effect is common, any drug deemed effective must prove itself stronger than a placebo.

The expectation of pain relief is enough to cause the brain to release painkilling endorphins. We believe this is so because brain scans show that essentially the same pain-suppression areas "light up" when patients take placebos or analgesic drugs.

The physical mechanisms that keep track of body position, movement, and balance actually consist of two different systems, the vestibular sense and the kinesthetic sense. The vestibular sense is the body position sense that orients us with respect to gravity. It tells us the posture of our bodies—whether straight, leaning, reclining, or upside down. The vestibular sense also tells us when we are moving or how our motion is changing. The receptors for this information are tiny hairs (much like those we found in the basilar membrane) in the semicircular canals of the inner ear. These hairs respond to our movements by detecting corresponding movements in the fluid of the semi-circular canals. Disorders of this sense can cause extreme dizziness and disorientation.

The kinesthetic sense, the other sense of body position and movement, keeps track of body parts relative to each other. Your kinesthetic sense makes you aware of crossing your legs, for example, and tells you which hand is closer to your cell phone when it rings. Kinesthesis provides constant sensory feedback about what the muscles in your body are doing during motor activities, such as whether to continue reaching for your cup of coffee or to stop before you knock it over (Turvey, 1996).

Receptors for kinesthesis reside in the joints, muscles, and tendons. These receptors, as well as those for the vestibular sense, connect to processing regions in the brain’s parietal lobes—which help us make a sensory “map” of the spatial relationship among objects and events. This processing usually happens automatically and effortlessly, outside of conscious awareness, except when we are deliberately learning the movements for a new physical skill, such as swinging a golf club or playing a musical instrument.

8.9 Conclusion

Different people probably have similar sensations in response to a stimulus because their sense organs and parts of the brain they use in sensation are similar. The brain does not sense the external world directly. The sense organs transduce stimulation and deliver stimulus information to the brain in the form of neural impulses. Our sensory experiences are, therefore, what the brain creates from the information delivered in these neural impulses.

8.10 Summary

Gustation is the sense of taste. Taste buds in the tongue receive molecules of substances, which fit into receptor sites. The five basic types of taste are sweet, sour, salty, bitter, and umami (brothy). Olfaction is the sense of smell. The olfactory receptors in the upper part of the nasal passages receive molecules of substances and create neural signals that then go to the olfactory bulbs under the frontal lobes. The somesthetic senses include the skin senses and the vestibular senses.

Pacinian corpuscles respond to pressure, certain nerve endings around hair follicles respond to pain and pressure, and free nerve endings respond to pain, pressure, and temperature. The gate-control theory of pain states that when receptors sensitive to pain are stimulated, a neurotransmitter called substance P is released into the spinal cord, activating other pain receptors by opening “gates” in the spinal column and sending the message to the brain. The kinesthetic senses allow the brain to know the position and movement of the body through the activity of special receptors responsive to movement of the joints and limbs. The vestibular sense also contributes to the body’s sense of spatial orientation and movement through the activity of the otolith organs (up-and-down movement) and the semi-circular canals (movement through arcs).

8.11 Key Words

::Anosmia

The loss of the ability to smell as a result of injury or infection.

::kinesthetic sense

Having to do with the location of body parts in relation to each other

:: Macrosmatic

Having a keen sense of smell that is important to their survival

::Microsmatic

Having a less keen sense of smell that is not crucial to their survival

::Olfaction

The sense of smell.

::Olfactory mucosa (OM)

A dime-sized region located high in the nasal cavity

::Phantom limb

The mysterious sensations often experienced by people who have lost an arm or leg

::placebos

Mock drugs made to appear as real drugs.

::skin senses

Having to do with touch, pressure, temperature, and pain

::Somesthetic sense

The body senses

::Vestibular senses

Having to do with movement and body position.

8.12 Check your progress:

1. The receptors on our taste buds work most like __________.
   a. receptors in the ears. c. receptor sites on neurons.
   b. receptors in the eyes. d. receptors in the skin.

2. Which of the following statements about olfactory receptorsis FALSE?
   a. Olfactory receptors are replaced every few years.
   b. There are at least 1,000 types of olfactory receptors.
   c. Signals from the receptors go directly to the olfactory bulbs in the brain.
   d. Olfactory receptors have hair like projections called cilia.

3. After some time has passed, you can no longer smell the odor of wet paint that you noticed when you first entered your classroom. Which is the most likely reason for this?
   a. The smell has gone away.
   b. You’ve adapted to the smell, even though it’s still there.
   c. Your nose fell asleep.
   d. You fell asleep.

4. Pain sensations in the skin, muscles, tendons, and joints that are carried on large nerve fibers are called __________.
   a. visceral pain.
   b. somatic pain.

c. referred pain.

d. indigenous pain.

5. In gate-control theory, substance P __________.

   a. opens the spinal gates for pain.

   b. closes the spinal gates for pain.

   c. is unrelated to pain.

   d. is similar in function to endorphins.

8.13 Answers to check your progress

1. c
2. a
3. b
4. b
5. a

8.14 Model Questions

1. Explain the process of chemical senses.
2. Describe the somesthetic senses.
3. Discuss the psychological techniques to reduce pain
4. Describe the process involved in olfactory sense.

LESSON 9
PROCESSING OF PERCEPTION

INTRODUCTION

Perception does not just happen, but is the end result of complex "behind the scenes" processes, many of which are not available to our awareness. One way to illustrate the behind-the-scenes processes involved in perception is by describing a sequence of steps, which is called as the perceptual process.

OBJECTIVES OF THE LESSON

After the completion of this lesson you will be able to understand

- how the perceptions are determined by the processes you are unaware of.
- the difference between perceiving something and recognizing it
- the importance of attention

Plan of the lesson

9.1 Perceptual process

The perceptual process, is a sequence of processes that work together to determine our experience of and reaction to stimuli in the environment. The perceptual process is divided into four categories: Stimulus, Electricity, Experience and Action, and Knowledge. Stimulus refers to what is out there in the environment, what we actually pay attention to, and what stimulates our receptors. Electricity refers to the electrical signals that are created by the receptors and transmitted to the brain. Experience and Action refers to our goal—to perceive, recognize, and react to the stimuli. Knowledge refers to knowledge we bring to the perceptual situation.

9.1.1 The Stimulus

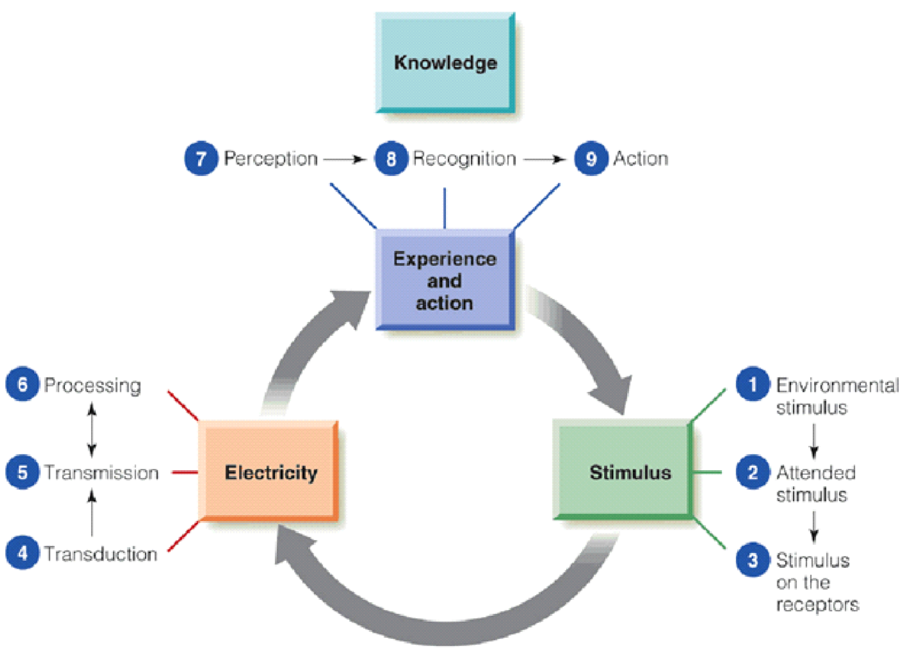

Figure 9.1

The stimulus exists both "out there," in the environment, and within the person's body. There are two aspects of the stimulus in the environment: Environmental Stimulus and Attended Stimulus. The environmental stimulus is all of the things in our environment that can be potentially perceived. Consider, for example, the potential stimuli that are presented to a person, who is taking a walk in the woods. As the person walks along the trail, is confronted with a large number of stimuli —trees, the walking path, the rustling noises made by a small animal scampering through the leaves. Because there is far too much happening it is difficult to take in everything at once. So, the individual scans the scene, looking from one place to another at things that are of his or her interest. When the attention is captured by a particularly distinctive looking tree off to the right, the individual shifts his focus on the tree, making it the center of his attention. This stimulus (tree) becomes the attended stimulus. The attended stimulus changes from moment to moment, as the individual shifts the attention from place to place.

9.1.2 The Stimulus on the Receptors

When the person focuses the attention on the tree, looks directly at it and this creates an image of the tree and its immediate surroundings on the receptors of her retina, a 0.4-mm-thick network of light-sensitive receptors and other neurons that line the back of the retina. This step is important because the stimulus—the tree—is transformed into another form—an image on the retina. Because the tree has been transformed into an image, it can be described as a representation of the tree. It's not the actual tree, but it stands for the tree. The next steps in the perceptual process carry this idea of representation a step further, when the image is transformed into electricity.

9.1.3 Electricity

One of the central principles of perception is that everything we perceive is based on electrical signals in our nervous system. These electrical signals are created in the receptors, which transform energy from the environment (such as the light on the retina) into electrical signals in the nervous system—a process called transduction.

9.1.3.1 Transduction

Transduction is the transformation of one form of energy into another form of energy. For example, when you touch the "withdrawal" button on an ATM machine, the pressure exerted by your finger is transduced into electrical energy, which causes a device that uses mechanical energy to push your money out of the machine.

Transduction occurs in the nervous system when energy in the environment—such as light energy, mechanical pressure, or chemical energy—is transformed into electrical energy. In our example, the pattern of light created on the individual's retina by the tree is transformed into electrical signals in thousands of his visual receptors.

9.1.3.2 Transmission

After the tree's image has been transformed into electrical signals in the receptors, these signals activate other neurons, which in turn activate more neurons. Eventually these signals travel out of the eye and are transmitted to the brain. The transmission step is crucial because if signals don't reach the brain, there is no perception.

9.1.3.3 Processing

As electrical signals are transmitted through the retina and then to the brain, they undergo neural processing, which involves interactions between neurons. To understand this we will compare how signals are transmitted in the nervous system to how signals are transmitted by your cell phone. Let's first consider the phone. When a person says "hello" into a cell phone, this voice signal is changed into electrical signals, which are sent out from the cell phone. This electrical signal, which represents the sound "hello," is relayed by a tower to the receiving cell phone, which transforms the signal into the sound "hello." An important property of cell phone transmission is that the signal that is received is the same as the signal that was sent.

The nervous system works in a similar way. The image of the tree is changed into electrical signals in the receptors, which eventually are sent out the back of the eye. This signal, which represents the tree, is relayed through a series of neurons to the brain, which transforms this signal into a perception of the tree. Thus, with a cell phone, electrical signals that represent a stimulus ("hello") are transmitted to a receiver (another cell phone), and in the nervous system, electrical signals representing a stimulus (the tree) are also transmitted to a receiver (the brain). There are, however, differences between information transmission in cell phones and in the nervous system. With cell phones, the signal received is the same as the signal sent. The goal for cell phones is to transmit an exact copy of the original signal. However, in the nervous system, the signal that reaches the brain is transformed so that, although it represents the original stimulus, it is usually very different from the original signal.

The transformation that occurs between the receptors and the brain is achieved by neural processing, which happens as the signals that originate in the receptors travel through a maze of interconnected pathways between the receptors and the brain and within the brain. In the nervous system, the original electrical representation of the stimulus that is created by the receptors is transformed by processing into a new representation of the stimulus in the brain.

9.1.4 Experience and Action

The next stage of the perceptual process, where the “backstage activity” of transduction, transmission, and processing is transformed into things we are aware of—perceiving, recognizing, and acting on objects in the environment.

9.2 Steps in Perception

Perception is conscious sensory experience. It occurs when the electrical signals that represent the tree are transformed by the brain into the experience of seeing the tree. Once it is perceived as tree the other things have happened as well—she has recognized the form as a “tree” and not a “pole,” and takes action based on the perception by walking closer to the tree to get a better look at it. These two additional steps—recognition and action—are behaviors that are important outcomes of the perceptual process.

9.2.1 Recognition

Recognition is our ability to place an object in a category, such as “tree,” that gives it meaning. Although we might be tempted to group perception and recognition together, they are separate processes. For example, consider the case of Dr. P., a well-known musician and music teacher, began misperceiving common objects, for example addressing a parking meter as if it were a person or expecting a carved knob on a piece of furniture to engage him in conversation, it became clear that his problem was more serious than just a little forgetfulness. It was clear from an eye examination that he could see well and, by many other criteria, it was obvious that he was not crazy. Dr. P.’s problem was eventually diagnosed as visual form agnosia—an inability to recognize objects—that was caused by a brain tumor. He perceived the parts of objects but couldn’t identify the whole object. The normally easy process of object recognition had, for Dr. P., been derailed by his brain tumor. He could perceive the object and recognize parts of it, but couldn’t perceptually assemble the parts in a way that would enable him to recognize the object as a whole. Cases such as this show that it is important to distinguish between perception and recognition.

9.2.2 Action

Action includes motor activities such as moving the head or eyes and locomoting through the environment. Action is an important outcome of the perceptual process because of its importance for survival. David Milner and Melvyn Goodale (1995) propose that early in the evolution of animals the major goal of visual processing was not to create a conscious perception or “picture” of the environment, but +to help the animal control navigation, catch prey, avoid obstacles, and detect predators—all crucial functions for the animal’s survival.

The fact that perception often leads to action—whether it be an animal’s increasing its vigilance when it hears a twig snap in the forest or a person’s deciding to look more closely at something that looks interesting—means that perception is a continuously changing process. The changes that occur as people perceive is the reason the steps of the perceptual process are arranged in a circle. Although we can describe the perceptual process as a series of steps that “begin” with the environmental stimulus and “end” with perception, recognition, and action, the overall process is so dynamic and continually changing that it doesn’t really have a beginning point or an ending point.

9.2.3 Knowledge

The perceptual process also includes—Knowledge. Knowledge is any information that the perceiver brings to a situation. Knowledge is placed above the circle because it can affect a number of the steps in the perceptual process. Information that a person brings to a situation can be things learned years ago, or knowledge obtained from events that have just happened. An example of how knowledge acquired years ago can influence the perceptual process is the ability to categorize objects. Another way to describe the effect of information that the perceiver brings to the situation is by distinguishing between bottom-up processing and top-down processing.

Bottom-up processing (also called data-based processing) is processing that is based on incoming data. Incoming data always provide the starting point for perception because without incoming data, there is no perception.

Top-down processing (also called knowledge-based processing) refers to processing that is based on knowledge. Knowledge isn’t always involved in perception but, as we will see, it often is—sometimes without even being aware of it.

Bottom-up processing is essential for perception because the perceptual process usually begins with stimulation of the receptors. Thus, when a pharmacist reads what to you might look like an unreadable scribble on your doctor’s prescription, she starts with the patterns that the doctor’s handwriting creates on her retina. However, once these bottom-up data have triggered the sequence of steps of the perceptual process, top-down processing can come into play as well. The pharmacist sees the squiggles the doctor made on the prescription and then uses her knowledge of the names of drugs, and perhaps past experience with this particular doctor's writing, to help understand the squiggles. Thus, bottom-up and top-down processing often work together to create perception.

9.3 Approaches to study of perception

The goal of perceptual research is to understand each of the steps in the perceptual process that lead to perception, recognition, and action which is simply known as perception. To accomplish this goal, perception has been studied using two approaches: the psychophysical approach and the physiological approach.

The psychophysical approach to perception was introduced by Gustav Fechner, a physicist who, coined the term psychophysics to refer to the use of quantitative methods to measure relationships between stimuli (physics) and perception (psycho). An example of research using the psychophysical approach would be measuring the stimulus–perception relationship (PP) by asking an observer to decide whether two very similar patches of color are the same or different.

The physiological approach to perception involves measuring the relationship between stimuli and physiological processes (PH1 in Figure 9.2) and between physiological processes and perception (PH2 in Figure 9.2).

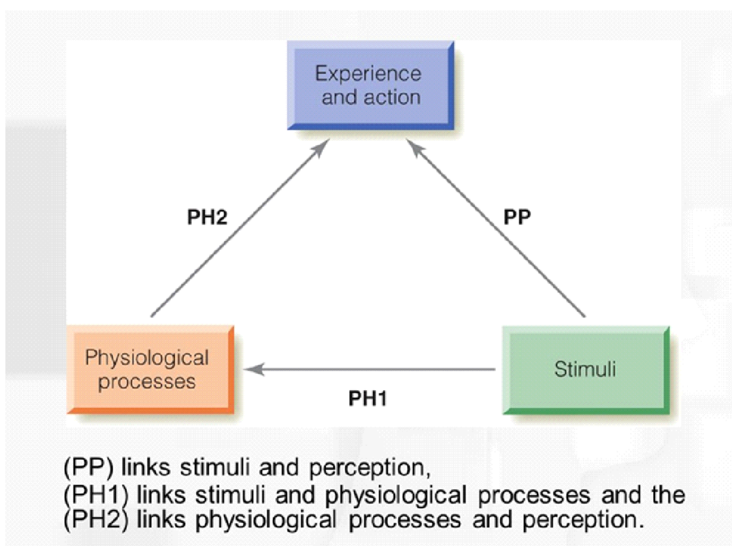

Figure 9.2

These physiological processes are most often studied by measuring electrical responses in the nervous system, but can also involve studying anatomy or chemical processes.

Though there is difference between the psychophysical approach and the physiological approach, they both are working toward a common goal—to explain the mechanisms responsible for perception. Thus, when we measure how a neuron responds to different colors (relationship PH1) or the relationship between a person's brain activity and that person's perception of colors (relationship PH2), our goal is to explain the physiology behind how we perceive colors. Anytime we measure physiological responses, our goal is not simply to understand how neurons and the brain work; our goal is to understand how neurons and the brain create perceptions. As we study perception using both psychophysical and physiological methods, we will also be concerned with how the knowledge, memories, and expectations that people bring to the situation influence their perceptions. These factors are called cognitive influences on perception. One of the things that becomes apparent from the psychophysical and physiological approaches is that each one provides information about different aspects of the perceptual process. Thus, to truly understand perception, we have to study it using both approaches.

9.4 Characteristics of human perception: The Stimulus on the Receptors Is Ambiguous

When you look at the page of this book, the image cast by the page on the retina is ambiguous. It may seem strange, because it is obvious that the page is rectangular, but viewed from straight on, the rectangular page creates a rectangular image on the retina. However, other objects, such as the tilted rectangle or slanted trapezoid, can also create the same image. The fact that a particular image on the retina (or a computer vision machine's sensors) can be created by many different objects is called the inverse projection problem. Another way to state this problem is as follows: If we know an object's shape, distance, and orientation, we can determine the shape of the object's image on the retina. However, a particular image on the retina can be created by an infinite number of objects. The information from a single view of an object can be ambiguous. Humans solve this problem by moving to different viewpoints, and by making use of knowledge they have gained from past experiences in perceiving objects.

9.4.1 Objects Can Be Hidden or Blurred

Sometimes objects are hidden or blurred. This problem of hidden objects occurs any time one object obscures part of another object. This occurs frequently in the environment, but people easily understand that the part of an object that is covered continues to exist, and they are able to use their knowledge of the environment to determine what is likely to be present.

9.4.2 Objects Look Different From Different Viewpoints

Another problem facing any perception is that objects are often viewed from different angles. This means that the images of objects are continually changing, depending on the angle from which they are viewed. The ability to recognize an object seen from different viewpoints is called viewpoint invariance. These difficulties proves that perception is more complex than it seems.

9.5 Attention

To understand perception as it happens in the real world, we need to go beyond just considering how we perceive isolated objects. Description of the processes involved in attention makes you to understand perception as it occurs within the richness of the natural environment. We begin by considering why we pay attention to specific things in the environment.

9.5.1 Perceiving the Environment

In everyday life we often have to pay attention to a number of things at once, a situation called divided attention. For example, when driving down the road, you need to simultaneously attend to the other cars around you, traffic signals, and perhaps what the person in the passenger seat is saying, while occasionally glancing up at the rear view mirror. But there are limits to our ability to divide our attention. For example, reading your textbook while driving would most likely end in disaster. Although divided attention is something that does occur in our everyday experience, our main interest is on selective attention—focusing on specific objects and ignoring others.

9.5.2 Selective Attention

One mechanism of selective attention is eye movements— scanning a scene to aim the fovea at places we want to process more deeply. The eye is moving constantly to take in information from different parts of a scene. Though eye movements are an important mechanism of selective attention, it is also important to note that there is more to attention than just moving the eyes to look at objects. We pay attention to things that are not directly on our line of vision and also can look directly at something without paying attention to it.

For example, while reading a book, you become aware that although you were moving your eyes across the page and “reading” the words, you have no idea what you just read. Even though you were looking at the words, you apparently were not paying attention. This example indicates tells us that there is a mental aspect of attention that occurs in addition to eye movements.

This connection between attention and what is happening in the mind was described more than 100 years ago by William James (1890/1981), in his textbook “Principles of Psychology”. According to James, we focus on some things to the exclusion of others. As you walk down the street, the things you pay attention to—a classmate that you recognize, the “Don’t Walk” sign at a busy intersection, and the fact that just about everyone except you seems to be carrying an umbrella—stand out more than many other things in the environment. There are several reasons behind this.

9.5.3 Stimulus Salience

Stimulus salience refers to characteristics of the environment that stand out because of physical properties such as color, brightness, contrast, or orientation. Areas with high stimulus salience are conspicuous, such as a brightly colored red ribbon on a green Christmas tree. Capturing attention by stimulus salience is a bottom up process—it depends solely on the pattern of stimulation falling on the receptors. But attention is not just based on what is bright or stands out. Cognitive factors are important as well. A number of cognitively based factors have been identified as important for determining where a person looks.

9.5.4 Knowledge About Scenes

The knowledge we have about the things that are often found in certain types of scenes and what things are found together within a scene can help determine where we look. There are situations in which your knowledge about specific types of scenes might influence where you look. You probably know a lot, for example, about kitchens, college campuses, automobile instrument panels, and shopping malls, and your knowledge about where things are usually found in these scenes can help guide your attention through each scene.

9.5.5 Nature of the Observer’s Task

When a person is carrying out a task, the demands of the task override factors such as stimulus saliency. This is explained by the fixations and eye movements that occurred as a person was making a peanut butter sandwich. The process of making the sandwich begins with the movement of a slice of bread from the bag to the plate. This operation is accompanied by an eye movement from the bag to the plate. The peanut butter jar is then fixated, then lifted and moved to the front as its lid is removed. The knife is then fixated, picked up, and used to scoop the peanut butter, which is then spread on the bread. The person fixated on few objects or areas that were irrelevant to the task and that eye movements and fixations were closely linked to the action the person was about to take. For example, the person fixated the peanut butter jar just before reaching for it.

9.5.6 Learning From Past Experience

If a person has learned the key components of making a peanut butter sandwich, this learning helps direct attention to objects, such as the jar, the knife, and the bread, that are relevant to the task.

It is clear that a number of factors determine how a person scans a scene. Salient characteristics may capture a person's initial attention, but cognitive factors become more important as the observer's knowledge of the meaning of the scene begins determining where he or she fixates. Even more important than what a scene is, is what the person is doing within the scene. Specific tasks, such as making a peanut butter sandwich or driving, exert strong control over where we look.

9.6 Role of attention in perception

Although there is no question that attention is a major mechanism of perception, there is evidence that we can take in some information even from places where we are not focusing our attention.

9.6.1 Effect of Lack of Focused Attention: Inattentional Blindness

Evidence that attention is necessary for perception is provided by a phenomenon called inattentional blindness— failure to perceive a stimulus that isn't attended, even if it is in full view.

Imagine looking at a display in a department store window. When you focus your attention on the display, you probably fail to notice the reflections on the surface of the window. Shift your attention to the reflections, and you become unaware of the display inside the window. Daniel

Simons and Christopher Chabris (1999) created a situation in which one part of a scene is attended and the other is not. They created a 75-second film that showed two teams of three players each. One team was passing a basketball around, and the other was “guarding” that team by following them around and putting their arms up as in a basketball game. Observers were told to count the number of passes, a task that focused their attention on one of the teams. After about 45 seconds, one of two events occurred. Either a woman carrying an umbrella or a person in a gorilla suit walked through the “game,” an event that took 5 seconds. After seeing the video, observers were asked whether they saw anything unusual happen or whether they saw anything other than the six players. Nearly half—46 percent— of the observers failed to report that they saw the woman or the gorilla.

In another experiment, when the gorilla stopped in the middle of the action, turned to face the camera, and thumped its chest, half of the observers still failed to notice the gorilla. These experiments demonstrate that when observers are attending to one sequence of events, they can fail to notice another event, even when it is right in front of them.

9.6.2 Change Blindness

Instead of presenting several stimuli at the same time, a stimulus is presented first, then another slightly different stimulus. People often have trouble detecting the change even though it is obvious when you know where to look. In a similar experiment in which people are presented with one picture, followed by a blank field, followed by the same picture but with an item missing, followed by the blank field, and so on. The pictures were alternated in this way until observers were able to determine what was different about the two pictures. It is found that the pictures had to be alternated back and forth a number of times before the difference was detected. This difficulty in detecting changes in scenes is called change blindness.

9.6.3 Enhancement of perception

William James stated that attending to a stimulus makes it more “clear and vivid.” Information processing is more effective at the place where attention is directed. There is also evidence that when attention is directed to one place on an object, the enhancing effect of this attention spreads throughout the object. In addition, paying attention to a location results in faster responding when a target is presented at that location. This “spreading enhancement” may help us perceive partially obscured object.

9.7 Conclusion

Perception involves several processes and steps which can be explained through the psychophysical and physiological approaches. Human perception happens because of unique characteristics which even a machine cannot do. Selective attention reduces the interference from irrelevant sensory sources.

9.8 Summary

The perceptual process is divided into four categories: Stimulus, Electricity, Experience and Action, and Knowledge. In addition perception involves recognition and action which completes the perceptual process. The steps in perceptual process can be understood through the psychophysical approach and physiological approach. Human perception has certain unique characteristics. Attention is an important determinant of perception. We can perceive some things, such as the gender of a face, without focused attention, but that focused attention is necessary for detecting many of the details within a scene and for detecting the details of specific objects in the scene.

9.9 Key Words

::Attended stimulus

The stimulus which captures the attention

:: Bottom-up processing (data-based processing)

Processing that is based on incoming data.

:: Change blindness.

Difficulty in detecting changes in scenes

:: Environmental stimulus

All of the things in our environment that can be potentially perceived

:: Inattentional blindness

Failure to perceive a stimulus that isn’t attended, even if it is in full view.

:: Knowledge

Any information that the perceiver brings to a situation.

:: Perception

Conscious sensory experience

:: Perceptual process

A sequence of processes that work together to determine our experience of and reaction to stimuli in the environment.

:: Physiological approach

Perception involves measuring the relationship between stimuli and physiological processes and between physiological processes and perception

:: Psychophysical approach

The use of quantitative methods to measure relationships between stimuli (physics) and perception (psycho)

:: Recognition

Our ability to place an object in a category that gives it meaning

:: Selective attention

Focusing on specific objects and ignoring others.

:: Stimulus

What stimulates our receptors.

:: Stimulus salience

Characteristics of the environment that stand out because of physical properties such as color, brightness, contrast, or orientation.

:: Top-down processing (knowledge-based processing)

Processing that is based on knowledge

:: Transduction

The transformation of one form of energy into another form of energy

:: Transmission

Activation of other neurons through the electrical signals

9.10 Check your progress

1. The first stage in perception process involves

   (a) Attention and meaning

   (b) Selection and attention

   (c) Stimulus and response

   (d) Attention and logic

2. Which of the following will influence an individual's perception

   (a) Individual needs

   (b) Previous experience

   (c) Sensory limitations

   (d) All of the above

3. A person's _____________ comprises internal factors such as ability, intelligence and personality, and will determine how an individual to certain stimuli

   (a) Perceptual set

   (b) Psychological threshold

   (c) Cognitive set

   (d) Sensory limit

4. The psychological factors affecting perceptual selection are

   (a) Learning, personality, ego

   (b) Personality, ego and mental processes

(c) Motives, personality, mental processes

(d) Personality, learning, motives

5. We tend to pay more attention to environmental stimuli which are

(a) Novel (b) Bright

(b) Moving (d) All the above

9.11 Answers to check your progress

1. b
2. d
3. a
4. d
5. d

9.12 Model Questions

1. What are two reasons that we focus on some things and ignore others?
2. What is selective attention?
3. What is divided attention?
4. Describe the factors that influence how we direct our attention in a scene.

LESSON 10

PERCEPTION

INTRODUCTION

Our perceptions are based on how we interpret all the different sensations, which are sensory impressions we get from the stimuli in the world around us. Perception enables us to navigate the world and to make decisions about everything, from which T-shirt to wear or how fast to run away from a bear. Perception involves the organization and interpretation of stimuli to give them meaning. To understand and recognise perception blends into cognition, a more complex and interpretive process involves memory and thought.

Objectives of the lesson

After the completion of this lesson you will be able to understand

- the approaches to perception
- perceptual constancies
- depth perception
- illusion

Plan of the lesson

10.1 Theoretical Explanations for Perception

10.2 Gestalt Theory

10.3 Learning-Based Inference: The Nurture of Perception

10.4 Perceptual constancy

10.5 Depth perception

10.6 Perceptual illusions

10.7 Conclusion

10.8 Summary

10.9 Key words

10.10 Check your progress

10.1 Theoretical Explanations for Perception

The fact that most people perceive most illusions and ambiguous figures in essentially the same way suggests that fundamental perceptual principles are at work. There are two influential theories that explain how we form our perceptions: Gestalt theory and learning-based inference. Although these two approaches may seem contradictory at first, they really emphasize complementary influences on perception. The Gestalt theory emphasizes how we organize incoming stimulation into meaningful perceptual patterns—because of the way our brains are innately "wired." On the other hand, learning-based inference emphasizes learned influences on perception, including the power of expectations, context, and culture. In other words, Gestalt theory emphasizes nature, and learning-based inference emphasizes nurture.

10.2 Gestalt Theory

A group of German psychologists, argued that the brain is innately wired to perceive not just stimuli but also patterns in stimulation. They called such a pattern a Gestalt, the German word for "perceptual pattern" or "configuration." Thus, from the raw material of stimulation, the brain forms a perceptual whole that is more than the mere sum of its sensory parts. This perspective is known as Gestalt psychology.

The Gestaltists liked to point out that we perceive a square as a single figure rather than merely as four individual lines. Similarly, when you hear a familiar song, you do not focus on the individual notes. Rather, your brain extracts the melody, which is your perception of the overall pattern of notes. Such examples, the Gestalt psychologists argued, show that we always attempt to organize sensory information into meaningful patterns, the most basic elements of which are already present in our brains at birth. Because this approach has been so influential, we will examine some of the Gestalt discoveries in more detail.

10.2.1 Figure and Ground

One of the most basic of perceptual processes identified by Gestalt psychology divides our perceptual experience into figure and ground. A figure is simply a pattern or image that grabs our attention. As we noted, psychologists sometimes call this a Gestalt. Everything else becomes ground, the backdrop against which we perceive the figure. A melody becomes a figure heard against a background of complex harmonies, and a spicy chunk of pepperoni becomes the figure against the ground of cheese, sauce, and bread that makes up a pizza. Visually, a figure could be a bright flashing sign or a word on the background of a page. And in the ambiguous faces/vase seen in Figure (10.1), figure and ground reverse when the faces and vase alternately “pop out” as figure.

Figure 10.1

10.2.2 Closure

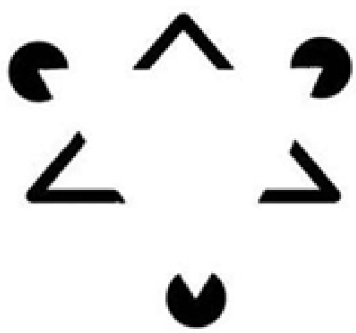

Figure 10.2

Our minds seem built to abhor a gap, as you saw in the figure above. Note especially the illusory white triangle—superimposed on the circles and black lines. Moreover, you will note that you have mentally divided the white area into two regions, the triangle and the background. Where this division occurs, you perceive subjective contours: boundaries that exist not in the stimulus but only in the subjective experience of your mind. Your perception of these illusory triangles demonstrates a second powerful organizing process identified by the Gestalt psychologists.

Closure makes you to see incomplete figures as wholes by supplying the missing segments, filling in gaps, and making inferences about potentially hidden objects. So when you see a face peeking around a corner, your mind automatically fills in the hidden parts of the face and body. In general, humans have a natural tendency to perceive stimuli as complete and balanced even when pieces are missing.

10.2.3 The Gestalt Laws of Perceptual Organization

Perceptual organization involves the grouping of elements in an image to create larger objects. There are six of the laws of organization that the Gestalt psychologists proposed to explain how perceptual grouping occurs.

10.2.3.1 Law of good figure or the law of simplicity: Pragnanz

Pragnanz, roughly translated from the German, means “good figure.” The law of pragnanz, also called the law of good figure or the law of simplicity, is the central law of Gestalt psychology: Every stimulus pattern is seen in such a way that the resulting structure is as simple as possible. The familiar Olympic symbol in Figure 10.3 is an example of the law of simplicity at work. We see this display as five circles and not as a larger number of more complicated shapes.

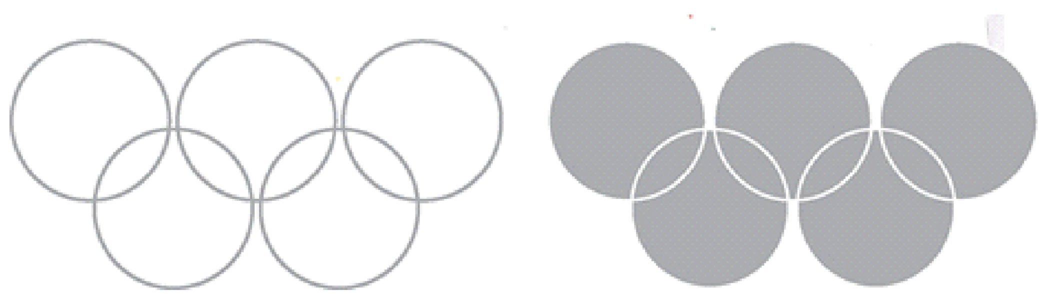

Figure 10.3

10.2.3.2 Law of Similarity

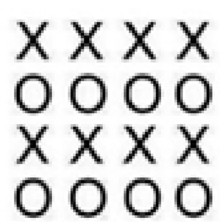

Figure 10.4

we group things together that have a similar look (or sound, or feel, and so on). So in Figure , you see that the X s and O s form distinct rows, rather than colomns, because of similarity. Likewise, when you watch a football game, you use the colors of the uniforms to group the players into two teams because of similarity, even when they are mixed together during a play. Any such tendency to perceive things as belonging together because they share common features reflects the law of similarity.

10.2.3.3Law of Good Continuation

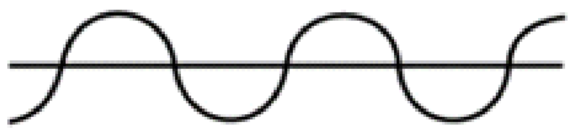

Figure 10.5

A straight line appears as a single, continuous line, even though a curved line repeatedly cuts through it. In general, the law of continuity says that we prefer smoothly connected and continuous figures to disjointed ones. Continuity also operates in the realm of social perception, where we commonly make the assumption of continuity in the personality of an individual whom we haven't seen for some time. So, despite interruptions in our contact with that person, we will expect to find continuity—to find him or her to be essentially the same person we knew earlier.

10.2.3.4 Law of Proximity (Nearness)

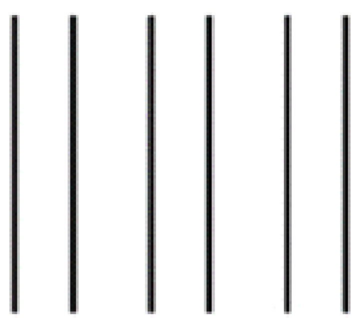

Figure 10.6

Our perception of Figure10.6 as three pairs of straight lines illustrates the law of proximity, or nearness: Things that are near each other appear to be grouped together.

10.2.3.5 Law of Common Region

Figure 10.7

Elements that are within the same region of space appear to be grouped together. Even though the circles inside the ovals are farther apart than the circles that are next to each other in neighboring ovals, we see the circles inside the ovals as belonging together. This occurs because each oval is seen as a separate region of space. Notice that in this example common region overpowers proximity. Because the circles are in different regions, they do not group with each other, as they did in Figure, but with circles in the same region.

10.2.3.6 Law of Uniform Connectedness

The principle of uniform connectedness states: A connected region of visual properties, such as lightness, color, texture, or motion, is perceived as a single unit.

Figure 10.8

10.2.3.7 Law of Synchrony

The principle of synchrony states: Visual events that occur at the same time are perceived as belonging together.

10.2.3.8 Law of Common Fate

The law of common fate states: Things that are moving in the same direction appear to be grouped together. Thus, when you see a flock of hundreds of birds all flying together, you