Rita Carter – The Human Brain Book, An Illustrated Guide to its Structure, Function, and Disorders

ISBN 978-0-7566-5441-2

THE BRAIN AND THE BODY

BRAIN SIZE, ENERGY USE, AND PROTECTION (44-45)

Weight and Volume
The average adult human brain weights about 3¼ lb (1.5 kg). Its volume and shape are similar to those of an average-sized cauliflower, and the consistency of its tissues is similar to stiff jelly. The size of a person's brain bear little relation to his or her intelligence, and every brain, whatever its weight and volume, has roughly the same number of neurons and synapses. After the age of 20 or so, brain mass decreases by about 1/32 oz (1g) per year. The brain shrinks as neurons die off and are not replaced. This is generally no cause for concern because there are plenty of neurons left to carry out the brain's function.

Intracranal Content
Brain tissue comprises gray and white matter, which consists of neurons and supporting glial cells respectively. A series of ventricles is filled with cerebrospinal fluids (CSF) and the brain is also richly supplied with blood vessels.

Composition of the Brain
The brain consists mainly of water, which occurs in the cytoplasm of neurons and glial cells, as well as being a major constituent of blood. The brain is also rich in lipids – fatty molecules that make up cell membranes.

Oxygen and Glucose Supply
Glucose is the brain's sole fuel, except under conditions of starvation, when it breaks down protein. The brain is by far the body's hungriest organ. Although it accounts for just 2 percent of the body's weight, it requires a staggering 20 percent of its total glucose supplies. This is obtained from dietary carbohydrate, which is transported to the brain via the bloodstream. It consumes roughly 4oz (120g) of glucose (about 420kcal) per day. Because the brain cannot store glucose, it must be readily available at all times via the blood supply. Without oxygen or glucose, the brain an last for only about 10 minutes before irreparable damage occurs. This is why prompt resuscitation is needed in cases or cardiac arrest.

BRAIN ANATOMY

BRAIN STRUCTURES (52-55)

The Brain Hierarchy
The brain's major parts can be classified or categorized in several ways. In all of these systems, the dominant part is the cerebrum, the large pinky-gray wrinkled structure that forms more than three-quarters of the brain's total volume. The cerebrum is divided into left and right hemispheres, which is linked by a “bridge” of nerve fibers, the corpus callosum. The cerebrum, which includes the hippocampus and amygdala, is also known as the telencephalon. Together, with the parts it wraps around – the thalamus, hypothalamus, and associated parts, collectively known as the diencephalon – it comprises the major brain “division” known as the forebrain (prosencephalon). Below the forebrain is the midbrain (mesencephalon), a small division that includes groups of nerve-cell bodies known as nuclei, such as the basal ganglia. Below the midbrain is the hindbrain

(rhombencephalon), with pons as its uppermost part, and beneath it is the cerebellum and the medulla, which tapers to merge with the spinal cord.

Left and Right Hemispheres

An overhead view of the "exploded" brain shows how the two cerebral hemispheres can be neatly separated by cutting through the corpus callosum. Many other brain structures are symmetrically paired in this way, such as the thalamus, which is sometimes described as "two hen's eggs sitting side by side." The cerebellum at the lower rear of the brain is accommodated within a bowl-like cavity of the skull known as the posterior cranial fossa. The cranial nerves […] enter the brain directly rather than connecting to the spinal cord.

BRAIN ZONES AND PARTITIONS (57)

The brain's physical structure broadly reflects its mental organization. In general, higher mental processes occur in the upper regions, while the brain's lower regions take care of basic life support.

Vertical Organization

The uppermost brain region, the cerebral cortex, is mostly involved in conscious sensations, abstract thought processes, reasoning, planning, working memory, and similar higher mental processes. The limbic areas […] on the brain's innermost sides, around the brainstem, deal largely with more emotional and instinctive behaviors and reactions, as well as long-term memory. The thalamus is a preprocessing and relay center, primarily for sensory information coming from lower in the brainstem, bound for the cerebral hemispheres above. Moving down the brainstem into the medulla are the so-called "vegetative" centers of the brain, which sustain life even if the person has lost consciousness.

Left and Right

Structurally, the left and right cerebral hemispheres look broadly similar. Functionally, however, speech and language, stepwise reasoning and analysis, and certain communicating actions are based mainly on the left side in most people. Since nerve fibers cross from left to right at the base of the brain, this dominant left side receives sensory information from, and sends messages to, muscles in the right side of the body – including the right hand. Meanwhile, the right hemisphere is more concerned with sensory inputs, auditory and visual awareness, creative abilities and spatial-temporal awareness (what happens in our surroundings, second by second).

THE NUCLEI OF THE BRAIN (58)

In the brain, nuclei are discrete collections of the cell bodies of neurons (nerve cells). Their nerve fibers or axons spread outward to project, or link, to various other brain parts. The brain has more than 30 sets of nuclei, mostly paired left and right.

General Structure

To the naked eye, most brain nuclei resemble "islands" of gray matter (nerve-cell bodies) within white mater of nerve fibers. Many nuclei are unencapsulated – not contained within a membrane or covering – so they may lack sharp delineation from surrounding tissue. An older term for some of these nuclei is "ganglia." However, this term is not usually reserved for similar structures in the peripheral nervous system, where groups of nerve-cell bodies are generally encapsulated into a discrete structure.

Connections and Functions

Most brain nuclei have multiple nerve connections, both inputs and outputs, and carry out wide-ranging functions. The C-shaped caudate nuclei above and to the side of thalamus, and next to the lateral ventricle, have a head part, main body, and tapering tail. They are involved in motor (muscle) control and also in learning and memory. The rounded putamen, the outermost of the mail basal ganglia, partly follows the shape of the caudate nucleus and is intricately linked anatomically to it. It, too, is heavily involved in motor control and movements, and in learning. The putamen has major nerve connections with the globus pallidus and substantia nigra. All of the basal ganglia work together as an integrated brain system to help ensure that physical movements are smooth and coordinated. Problems with one or more of the nuclei can lead to movement disorders such as tremors, tics, Parkinson's disease, Tourette's syndrome, and Huntington's chorea. The subthalamic nuclei also have roles in impulsive actions and movement intentions.

THE THALAMUS, HYPOTHALAMUS, AND PITUITARY GLAND (60-61)

The thalamus is situated at the anatomical core of the brain. Its position makes it perfectly situated to act as a relay station between the sense organs and the brain. Sitting beneath the thalamus, the hypothalamus and the pituitary gland link the central nervous system and the endocrine system.

The Thalamus

Paired, egg-shaped masses that sit side by side make up the thalamus. In a typical brain, each mass is about 1¼in (3cm) long and ½in (1.5cm) across. There are no direct nerve connections from one mass to the other – in fact, the fluid-filled chamber of the third ventricle lies between them. The thalamus is the major relay station for nerve signals coming from all the senses except smell. It screens, sorts, and preprocesses this continuing torrent of sensory information and sends it on to the cerebral cortex.

The Hypothalamus

Not much larger than the end segment of the little finger, weighing just 5/32 oz (4g), and comprising only 0.4 percent of total brain volume, the hypothalamus has many and varied vital roles – in conscious behavior, emotions and instincts, and automatic control of body systems and processes. It consists of more than a dozen paired nuclei (regions of interlinked nerve-cell bodies) clustered into the floor of the diencephalon and separated by the lateral ventricle. Its secretory cells make hormones (called releasing factors) that enter the blood stream, and its neurosecretory cells produce hormonelike substances that travel along nerve axons down to the pituitary gland.

The Pituitary Gland

The hypothalamus integrates the body's two systems for coordination and control: the nervous system around and above it and the endoctine system via the pituitary just below it. The pea-sized pituitary (hypophysis), often called the body's "master hormone gland," has two distinct lobes. The anterior lobe (adenohypophysis) makes several hormones that release into the bloodstream to regulate other endocrine glands around the body, such as the thyroid. The posterior lobe (neurohypophysis) receives two hormones along axons from the hypothalamus.

THE BRAINSTEM AND CEREBELLUM (62-63)

The brainstem is perhaps misnamed. It is not a stem leading to the separate brain above, but an integral part of the brain itself. It is shaped rather like a widening upright stalk, on top of which are the thalamus and the dome of the cerebral hemispheres. Curled around the lower brainstem, at the rear of the brain, sits the cerebellum.

Brainstem Anatomy

The brainstem includes almost all of the brain except for the highest parts, which make up the forebrain (cerebrum and diencephalon). Its uppermost region is the midbrain comprising an upper "roof" or tectum incorporating the superior and inferior colliculi or bulges at the rear, and the tegmentum to the front. Below the midbrain is the hindbrain. At its front is the large bulge of the pons. Behind and below this is the medulla, which narrows to merge with the uppermost end of the body's main nerve, the spinal cord. The cerebellum joins to the rear of the medulla b three pairs of stalks, known as the cerebellar penduncles.

Brainstem Functions

The brainstem is highly involved in mid- to low-order mental activities, for example, the almost "automatic" scanning movements of the eyes as we watch something pass by, rather than higher activities such as abstract thought. It is also the site of subconscious or automatic control mechanism, of which we are usually unaware. The medulla, in particular, houses groups of nuclei that are centers for respiratory (breathing), cardiac (heartbeat), and vasomotor (blood pressure) monitoring and control, as well as for vomiting, sneezing, swallowing, and coughing.

The Cerebellum

The "little brain" is the lower, rearmost part of the entire brain. It resembles the wrinkled appearance of the cerebrum above, but its grooves and bulges are finer and organized into more regular patterns. Major anatomical parts of the cerebellum include: the long, slim vermis ("worm") in the center; two flocculonodular lobes beneath, one on each side; and outside these, two much larger lateral lobes, each of which is divided into several lobules. The two lateral lobes are reminiscent of the two hemispheres of the cerebrum and are sometimes termed cerebellar hemispheres. The cerebellum's main functions are to coordinate body movements through integrated control of muscles, including balance and posture, and equilibrium.

THE LIMBIC SYSTEM (64)

The limbic system is involved in instinctive behaviors, deep-seated emotions, and basic impulses such as sex, anger, pleasure, and general survival. It also forms a link between centers of higher consciousness, in the cerebral cortex, and the brainstem, which regulates the body's systems.

Components of the Limbic System

The Limbic system includes the areas of the cortex and adjacent parts known as the limbic lobe […], along with the amygdala, hypothalamus, thalamus, mamillary bodies, and other deeper, more central brain structures. The system is also "hard-wired" into parts of the sensory system, especially the sense of smell. Nerve fibers link all of these parts intimately and also connected them to other areas of the brain, particularly the lower frontal cortex, with its roles in expectation, reward, and decision-making.

The Hippopotamus

The hippopotamusus is strung along the upper edge of the parahippocampal gyrus. The hippocampus interlocks with another ridge, known as the dentate gyrus – together the two form the hippocampal-dentate complex. It is part of the cerebral cortex, but it has only one, two, or three layers of cells, rather than the usual six layers found in most of the more "advanced" regions of the cortex.

The main functions of the hippocampus include spacial awareness, and memory formation and recall. In particular, the hippocampus helps select transient information for memorizing and then pass it though to longer-term memory areas. Damage to it can prevent a person from forming new memories, even though memories from before the damage are intact.

THE CEREBRAL CORTEX (66)

The cerebral cortex is the outer layer of the brain's most dominant part, the cerebrum. It is the bulging wrinkled surface we see when looking at the brain from any angle. It is commonly known as gray matter from its color, which contrasts with the white matter in the layer below.

The cerebral Lobes

Bulges and grooves help divide the cortex into four to six paired lobes, according to the anatomical system used. The main and deepest groove is the longitudinal fissure that separates the cerebral hemispheres. Both the extent and the names of the lobes are also partly related to the overlying bones of the skull, known as the neurocranium. For example, the two frontal lobes are approximately beneath the frontal bone, and likewise for the occipital lobes under the occipital bone. In some naming systems, the limbic lobe and the insula, or central lobe, are distinguished as separate from other lobes.

Functional Areas

The cortex can be "mapped" in three ways. One is by gross anatomy, as defined by sulci and gyri. A second is by microscopic anatomy – the shapes and types of cells and their connections, as pioneered by Korbinian Brodmann. […] the third method is by neurologica function, when small areas are stimulated to study the sensations or movements this produces. The three "maps" only partially coincide.

BRAIN CELLS (68)

The individual units of the brain and nervous system are microscopic nerve cells or neurons. Estimates of the number of brain neurons range from 50 billion to ten times that number – and they are not even the most numerous cells in the brain.

Neurons

Like hepatocyte cells in the liver, osteocytes in bone, or erythrocytes (red cells) in blood, each neuron is a self-contained functioning unit. Its internal components, the organelles, include a nucleus harboring the genetic material (DNA), energy-providing mitochondria, and protein-making ribosomes. As in most other types of cells, the organelles are concentrated in the main cell body. In addition, characteristic features of neurons are neurites – long, think, fingerlike or threadlike extensions from the cell body (soma). The two main types are dendrites and axons. Usually dendrites receive nerve signals, while axons send them onward.

Types of Neurons

Neurons can be categorized structurally according to the location of the cell body in relation to the axon and dendrites, and also the number of dendrites and axon branches. In some regions of the brain, peripheral nervous system, and sense organs, neuron types are organized and easily recognized. For example, the retina of the eye contains ranks of bipolar neurons. However, in many other regions the neurons are mixed in shape and form a complex, interconnected web. In the cortex, one neuron may receive signals from many thousands of other neurons via its multitudinous branching dendrites. Signals are conducted to the soma, around this, and then away along the axon – always by the cell membrane, not through the cytoplasm.

Support Cells

Less than 10 percent of the cells in the brain are neurons. Most of the rest are glial or support cells. They both provide physical support for the amazingly thin dendritic and axonal processes that wind their way around the network, and also supply nutritional support for the neurons in the form of sugars, raw materials for growth and maintenance, and other nutrients. There are several types of glial cells. Microglia destroy invading microbes and clear away debris from degenerating neurons. Oligodendrocytes manufacture myelin sheathing, a task performed in peripheral nerves by Schwann cells.

Synapses

Synapses are communication sites where neurons pass nerve impulses among themselves. The cells are not usually in actual physical contact, but are separated by an incredibly think gap, called the synaptic cleft. Microanatomically, synapses are divided into types according to the sites where the neurons almost touch. These sites include the soma, the dendrites, the axons, and tiny narrow projections called dendritic spines found on certain kinds of dendrites. Axospinodendritic synapses form more than 50 percent of all synapses in the brain; axodendritic synapses constitute about 30 percent.

NERVE IMPULSES

A nerve impulse or signal can be thought of as a tiny, brief “spike” of electricity traveling through a neuron. At a more fundamental level, it consists of chemical particles moving across the cell's outer membrane, from one side to the other.

Anatomy of an Impulse

Nerve signals are composed of series of discrete impulses, also known as action potentials. A single impulse is caused by a traveling “wave” of chemical particles called ions, which have electrical charges and are mainly the minerals sodium,potassium, and chloride. In the brain, and throughout the body, most impulses in most neurons are of the same strength – about 100 millivolts (0.1 volt). They are also of the same duration – around one millisecond (1/1,000 of a second) – but ravel at varying speeds. The information they convey depends on how frequently they pass in terms of impulses per second, where they came from, and where they are heading.

At the Synapse

The synaptic cleft separating the membranes of the sending (presynaptic) and the receiving (postsynaptic) cell has a width of some 20 nm (20 billionth of a meter). This is so narrow that the neurotransmitter molecules can pass across it extremely quickly by simple diffusion – moving from a region of higher concentration to tone of lower concentration. Depending on the neurotransmitter, the time taken for the impulse to pass from the pre- to postsynaptic membranes is typically less than 2 ms (1/500 of a second). There is then a recovery delay or clearance time, as the concentrations of neurotransmitter subside, before the next impulse can be sent across. This may last several tenths of a second.

Neurotransmitters

Neurotransmitters are chemicals that allow signals to pass between a neuron and another cell. There are several groups of neurotransmitter molecules. One contains only acetylcholine. A second is known as biogenic amines, or monoamines, and includes dopamine, histamine, norepinephrine, and serotonin. The third groups is composed of amino acids, such as GABA, glutamic acid, aspartic acid, and glycine. Many of these substances have other roles in the body. For example, histamine is involved in the inflammatory response. Amino acids (apart from GABA) are also very common, being the building blocks for hundreds of kinds of protein molecules.

THE SENSES

HOW WE SENSE THE WORLD (76-77)

The brain reaches out to the environment via our sense organs, which respond to various stimuli such as light, sound waves, and pressure. The information is transmitted as electrical signals to specialized areas of the cerebral cortex (the outer layer of the cerebrum) to be processed into sensations such as vision, hearing, and touch.

Mixed Senses

Sensory neurons respond to data from specific sense organs. Visual cortical neurons, for example, are most sensitive to signals from the eyes. But this specialization is not rigid. Visual neurons have been found to respond more strongly to weak light signals if accompanied by sound, suggesting that they are activated by data from the ears as well as the eyes. Other studies show that in people who are blind of deaf, some neurons that would normally process visual or auditory stimuli are “hijacked” by the other senses. Hence, blind people hear better and deaf people see better.

Synesthesia

Most people are aware of only a single sensation in response to one type of stimulus. For example, sound waves make noise. But some people experience more than one sensation in response to a single stimulus. They may "see" sounds as well as hear them, or "taste" images. Called synesthesia, this sensory duplication occurs when the neural pathway from a sense organ diverges and carries data on one type of stimulus to a part of the brain that normally processes another type.

Conscious and Unconscious Sensation

Our brains are bombarded with sensory information, but only a fraction of it reaches consciousness. Most sensory signals fizzle out unnoticed. Especially "loud" or important data grabs our attention, and we become conscious of it. Sensations we are not conscious of may still guide our actions. For example, unconscious sensations relating to our body position allow us to move without thinking about it. Also, sights and sounds that we fail to notice may nevertheless influence our behavior.

Blindsight

Blindsight gives visual knowledge without conscious vision. It is likely that we all have it, but it is most easily measured in people who are blind due to cortical damage. Such people cannot knowingly see, but if something is put in front of them they can correctly "guess" what it looks like, without knowing how. Most blindsight studies use moving objects. The subjects say they can't see the objects, but can usually "guess" the direction of movement correctly.

THE VISUAL CORTEX (80-81)

The visual areas of the brain are at the back of the brain; therefore, information from the eyes has to travel the full depth of the skull before it begins to be processed into sight. Visual information can guide actions within one-fifth of a second, but it takes about half a second for us to see an object consciously.

Visual Areas

The visual cortex is divided into several functional areas, each of which specializes in a particular aspect of vision. The process is similar to assembly-line production: raw material is checked in by V1, then sent on to other vision areas, which contribute shape, color, depth, and motion. These components are then combined to form a whole image. Because of the modular nature of vision, if one of the sight areas is damaged, a particular vision component may be lost while the others remain intact. Cell death in the motion-detecting area, for example, may cause the world to be seen as a series of still snapshots.

Distinguishing Colors

In theory the human visual system can distinguish millions of colors, but in practice the number of colors we see depends on whether we have learned to see them. Presented with a globe showing all possible colors, people can easily distinguish those for which they have distinct names. But if a range of hues is lumped together under a single name, they often find it hard to see the differences.

Recognizing Objects

Conscious sight requires the brain to recognize what it is seeing. To achieve this, the image is forwarded from the occipital lobe to other brain areas concerned with emotion and memory. Here it gains information relating to its function, its identity, and its emotional significance. One of the first stops is in the object-recognition area, which runs along the bottom rim of the temporal lobe. Human faces are dealt with in a particular subregion that has evolved to make fine distinctions. Its ability to distinguish tiny differences between individual faces makes nearly all of us "experts" at recognizing one another.

Depth and Dimension

The brain uses two types of cues to produce our three-dimensional view of the world. One is the slightly different image recorded by each eye (spatial binocular disparity), and the other is the way the perceived shape of an object shifts as it moves. Both cues come together in an area of the brain called the anterior intraparietal area (AIP), which lies between the visual processing areas and the part of the brain devoted to monitoring our position in space.

VISUAL PATHWAYS (82-83)

Dorsal – The "Where" Pathway

The dorsal, or "where," pathway carries signals triggered by a visual stimulus – for example, the light bounding off a nearby object – from the visual cortex to the parietal cortex. Along the way, it passes through areas that calculate the object's location in relation to the viewer and creates an action plan in relation to it. The dorsal path gathers information about motion and timing that is integrated into the action plan. All the information needed to, say, duck a flying object, is gathered along this path with no need for conscious thought.

Ventral – The "What" Pathway

The ventral, or "what," pathway follows a route that takes it first through a series of visual processing areas, each of which ads a specific aspect of perception, such as a shape, color, depth, and so on. The loosely formed representation then passes into the bottom edge of the temporal lobe, where it is matched or compared to visual memories in order to achieve recognition. Some information continues along this pathway to the frontal lobes, where it is assessed for meaning and significance. At this stage, it becomes a conscious perception.

Damage to the Dorsal Pathway

Damage to the dorsal visual pathway causes a number of disorders, all of which affect the ability to deal with objects in space. A person may, for example, be unable to see that two objects are in different places or to correctly see their spatial relationship, one to the other. They may find it impossible to reach out and grasp an object accurately or to know where it lies in relation to themselves. For example, a person may say something like, "I know there is a banana there but I don't know where it is." patients may also suffer visual attention defects.

Still Life

The ability to see movement is vital for survival. Many animals, such as frogs, can only see things in motion. The motion area of the human brain is tiny and more than 90 percent of neurons here are specialized to detect direction of movement. It is generally well protected from injury but, very rarely, a person may lose motion vision due to a stroke. The effect is profoundly disturbing, reducing the world to a series of snapshots. Day-to-day life becomes difficult – crossing the road, for example, is perilous as approaching traffic appears to first to be distant and then suddenly close. Pouring a cup of tea is difficult because the column of liquid seems to be frozen and then overflowing.

THE EAR (88-89)

The Anatomy of Hearing

The ear is divided into three sections: the outer ear, the middle ear, and the inner ear. The outer ear funnels sound waves along the ear canal to the eardrum (tympanic membrane) – the start of the middle ear. The sound waves cause the eardrum to vibrate, which in turn causes a chain of bones, known as the ear ossicles, to vibrate. One of these, the stapes, is attached to a membrane known as the oval window – the start of the inner ear. Beyond this is the maze of fluid-filled chambers of the spiral-shaped cochlea. The vibrations of the staples on the oval window are converted into pressure waves, which travel in the fluid within the cochlea to the organ of Corti. Sensory hair cells on this organ transform the pressure waves into electrical impulses, which travel through the auditory nerve (specifically, the cochlear branch of the vestibulocochlear nerve) to the brain.

The Auditory Cortex
Sound information, in the form of electrical impulses, travels from the ear along the auditory nerve to the auditory cortex (situated in the temporal lobe, beneath the temples) for processing. In one of its three areas, the primary auditory cortex, different auditory neurons respond to specific sound frequencies. Also, some respond to the intensity of a sound rather than to its frequency, while others respond to more complex sounds, such as clicks, animal noises, and bursts of noise. It is thought that the secondary auditory cortex plays a part in processing harmony, rhythm, and melody, while the tertiary auditory cortex is involved in integrating the variety of sounds into a whole impression.

Auditory Ranges
Many animals can hear sounds that humans cannot, both at higher and lower frequencies. Some animals pick up frequencies significantly higher than those humans can detect. For example, bats using echolocation can detect reflected sounds in the 14,000-100,000 Hertz range. The lower limit of the human auditory frequency range is fixed throughout life, but the upper limit begins to fall from adolescence. The maximum frequency heard by a normal middle-aged adult is between 14,000 and 16,000 Hertz.

Auditory Disorders
Hearing loss is common but total deafness is rare and usually results from a congenital problem. Mild or severe hearing loss can result from ear disease, injury, or degeneration of the hearing system with age. Hearing loss is either conductive (a fault in the transfer of sound from the outer to inner ear) or sensorineural (sometimes known as nerve deafness, involving damage to the auditory nerves, or to the sensory parts of the inner ear). Common hearing disorders include otitis media and otosclerosis. Otitis media mainly affects young children and is an inflammation of the middle ear caused by a bacterial infection. Otosclerosis occurs when there is abnormal bone growth on the stapes bone of the middle ear, which stops it from vibrating and conducting sound waves on to the inner ear.

MAKING SENSE OF SOUND (90-91)

Perception of Sound
Sounds start as vibrations entering the ears. In the inner ear, receptor cells in the cochlea transform these vibrations into electrical signals, which pass along the cochlear nerve to the medulla in the brainstem, and then to the inferior colliculus. The cochlear nerve fibers divide so that most of the input from each ear can go to both hemispheres. Processing at this stage enables the brain to determine the location of a sound. The signals reach the auditory cortex via the thalamus, where features such as frequency, intensity, quality, and meaning are perceived. The left auditory cortex is more concerned with the meaning and identification of sound; the right, with quality.

Noise or Music
Sound consists of waves, or vibrations, whose characteristics are determined by the source of the sound. The main characteristics influencing our perception of sound are frequency […] and amplitude […]. frequency influences pitch, and amplitude governs loudness. Irregular sound-wave patterns tend to be experienced as noise; in contrast, music produces regular patterns.
Music is hard to define precisely, but the quality of musical notes depends upon their sound source – a musical instrument – and how it is being played. Another important factor in music is timbre,

or the “quality” of a sound. Timbre depends upon how many different frequencies of the note are heard at once; multiple frequencies or overtones (harmony) make a richer timbre. The auditory cortex responds to different qualities in music. The primary region responds to frequencies and the secondary area to harmony and rhythm, while the tertiary area adds higher levels of appreciation and integration.

Development of Hearing

The development of hearing is a gradual process that begins in the womb and is complete by about the end of the first year of a baby's life. Research shows that the unborn child is capable of hearing by about the fourth month of gestation, but the auditory apparatus is not fully formed until about the sixth month. At birth, hearing is the most developed of the senses, so it is pf prime importance to the baby in exploring its world. Studies have shown how the baby learns to recognize sounds in its first few months, gradually becomes able to distinguish between speech and non-speech sounds, and then begins to understand words. Children also lose the ability to hear differences between sounds that are not important in their native language. Many Japanese children, for example, can no longer hear the difference between “l” and “r,” which they could distinguish at an earlier age.

SMELL (94-95)

Detecting Smell

Like the sense of taste, smell is a chemical sense. Specialized receptors in the nasal cavity detect incoming molecules, which enter the nose on air currents and bind to receptor cells. Sniffing sucks up more odor molecules into the nose, allowing you to “sample” a smell. It is a reflex action that occurs when a smell attracts your attention, and can help warn of danger, such as smoke from a fire or rotting food. Olfactory receptors located high up in the nasal cavity send electrical impulses to the olfactory bulb, in the limbic area of the brain for processing.

Receptor Arrays

There are around 1,000 types of receptor cell in the nasal cavity, but we an distinguish around 20,000 different smells so, clearly, there is more to smell reception that “one receptor, one smell.” Research shows that each receptor has zones on it, each of which responds to a number of smell molecules. Also, multiple receptors respond to the same smell molecule – it may be that each receptor binds to a different part of it. A specific smell will activate a specific pattern or “array” across the receptors, so that each smell has its own “signature.” When the receptors forming a specific pattern are activated, this signature is sent to the brain for processing.

The Chemistry of Smell

There is still much to be learned about the relationship between chemical structure and smell. Scientists have identified eight primary odors (rather like the three primary colors): camphorous, fishy, malty, minty, musky, spermatic, sweaty, and urinous. Smells are often produced by a combination of many different smell molecules, often from different categories. Comparisons of the structures of smell molecules within each category have shown some similarities – for example, minty smelling compounds often share a similar molecular structure. However, tiny differences in molecular structure can produce very different smells. Octanol, a fatty alcohol, smells like oranges, while octanoic acid, a saturated fatty acid that differs from octanol by only one oxygen atom, smells like sweat.

PERCEIVING SMELL (96-97)

The Evolution of Smell

The smell brain, centered around the olfactory bulb in the limbic system, is of ancient origin, having evolved about 50 million years ago in fish. The sense of smell was overtaken in importance by the sense of vision when humans began to walk on two legs, although it is still dominant for many animals. But smell is an important aspect of survival for humans, shown in the fact that we take prompt action if we smell gas or smoke, for example. It also plays an important role in sexual selection, emotional responses, and forming preferences for food and drink. All of these factors were probably of key importance in the lives of our ancestors.

Smell and Memory

An event is associated with input from all the senses, co-ordinated by the hippocampus. Reexperiencing any of the sight, smell, or sound inputs may trigger a memory of the event, but smell seems most strongly associated with memory. This may be because olfactory regions are linked to all emotional areas in the limbic system. Research shows that a memory of a visual image is likely to fade within days, but the memory of a smell may persist for up to a year or even decades. The hippocampus may not even be crucial for the link, because people who sustain damage to this region can still recall scents from their childhood, even though suffering from general memory loss.

Smell and Communication

Animals emit compounds called pheromones that are used as communication signals and detected by an accessory olfactory system in the brain. Humans recognize each other in a similar way – for example, infants prefer the smell of their mother's breast to that of other women. Research into the existence of pheromones in humans has found that women's menstrual cycles can synchronize when one woman is exposed to odorless compounds (supposing that these are pheromones) emitted from the underarms of another woman. In animals, the accessory olfactory system is linked to the vomeronasal region (VMO), an area in the nasal cavity that responds to pheromones. The VMO's existence in humans remains debatable.

TASTE (98-99)

The Evolution of Taste

The sense of taste enables animals, including humans, to make the most of the variety of foods available to them. Many plants that look tempting are toxic, so genes that enable us to detect (and therefore avoid) these toxins have an obvious survival value. One such gene that has been identified affords taste sensitivity to phenylthiocarbamide (PTC), an organic compound that resembles many toxic compounds found in plants.

The Tongue

The tongue is the main sensory organ for taste detection. It is the body's most flexible muscular organ, as revealed by its work in both nutrition and communication. It has three interior muscles and three pairs of muscles connecting it to the mouth and throat. Its surface is dotted with tiny, pimplelike structures called papillae. Other parts of the mouth, such as the palate, pharynx, and epiglottis can also detect taste stimuli.

Taste and Smell Brain Areas

Taste and smell are both chemical senses – receptors in the nose and mouth bind to incoming molecules, generating electrical signals to send to the brain. Both sets of signals pass along the cranial nerves. Smell-related (olfactory) signals travel from the nose to the olfactory bulb, then along the olfactory nerve to the olfactory cortex in the temporal lobe for processing. The pathway of taste-related (gustatory) data travels from the mouth along branches of the trigeminal and glossopharyngeal nerves to the medulla, continues to the thalamus, then to primary gustatory areas of the cerebral cortex.

Taste Associations

When a food makes you ill (spoiled seafood, for example), the association can linger for a long time, making even the thought of that food repulsive. The phenomenon, known as flavor-aversion learning, has been demonstrated by researchers at Harvard Medical School who fed rats a sweet liquid with a substance that made them briefly ill. Thereafter, the rats avoided the liquid despite its tempting sweetness. When a food is paired with nausea, flavor-aversion learning has a survival value in teaching animals to avoid attractive-looking foods that may be toxic. It is a robust form of learning – occurring after one episode only, but lasting for many years.

TOUCH (100-101)

Touch Receptors
There are around 20 types of touch receptor that respond to various types of stimuli. For instance, light touch, a general category that covers sensations ranging from a tap on the arm to stroking a cat's fur, is detected by four different types of receptor cells: free nerve endings, found in the epidermis; Merkel's disks, found in deeper layers of the skin; Meissner's corpuscles, which are common in the palms, soles of the feet, eyelids, genitals, and nipples; and, finally, the root hair plexus, which responds when the hair moves. Pacinian and Ruffini corpuscles respond to more intense pressure. The sensation of itching is produces by repetitive, low-level stimulation of nerve fibers in the skin, while feeling ticklish involves more intense stimulation of the same nerve endings when the stimulus moves over the skin.

Touch Pathways
When a sense receptor is activated, it sends information about touch stimuli as electrical impulses along a nerve fiber of the sensory nerve network to the nerve root on the spinal cord. The data enters the spinal cord and continues upward to the brain. The processing of sensory data is begun by nuclei in the upper (dorsal) column of the spinal cord. From the brainstem, sensory data enters the thalamus, where processing continues. The data then travels to the postcentral gyrus of the cerebral cortex, the location of the somatosensory cortex. Here, it is finally translated into a touch perception.

Somatosensory Cortex
Touch sensations are turned into perceptions in the somatosensory cerebral cortex, which curls around the brain like a horseshoe. Data from the left side of the body ends on the right side of the brain, and vice versa. Each part of the cortex processes data from a different part of the body. It is possible to make a map of the cerebral cortex, dividing it into regions that correspond to distinct body parts. Such a map was first drawn by Wilder Penfield, a renowned Canadian neurosurgeon. Touch receptors are unevenly distributed across the body. For example, experiments show that the distance between touch receptors is far greater on the back than on the lips. The hands have the largest proportion of touch receptors in the body.

THE SIXTH SENSE (102-103)

What is Proprioception?
Proprioception is our sense of how our bodies are positioned and moving in space. This "awareness" is produced by part of the somatic sensory system, and involves structures called proprioceptors in the muscles, tendons, joints, and ligaments that monitor changes in their length, tension, and pressure linked to changes in position. Proprioceptors send impulses to the brain. Upon processing this information, a decision can be made – to change position or to stop moving. The brain then sends signals back to the muscles based on the input from the proprioceptors – completing the feedback cycle.

Types of Proprioception

Proprioceptive information is either made conscious or processed unconsciously. For example, keeping and adjusting balance is generally an unconscious process. Conscious proprioception usually involves some kind of cortical processing, resulting in decision-making. This normally ends in a command to the muscles to perform a movement. The sheer amount of propropiceptive input means that much is processed unconsciously.

Phantom Limbs
When someone has a part of the body amputated or removed – be it a limb, an extremity, or an organ, such as appendix – they sometimes continue to have sensations, often including pain, in that area. Research has linked this to changes in the sensory cortex. Specifically, the somatosensory cortex undergoes a remapping process in which the areas near the "dead" area "take over", so that stimuli in these areas are felt as sensations in the area that has been lost. This reorganization of the cortex has been confirmed through imaging studies.

MOVEMENT AND CONTROL

REGULATION (110-111)

The Reticular Formation
The reticular formation is located in the brainstem and is made up of a series of long nerve pathways that modulate sensory inputs and carry information to and from the cerebral cortex. It also plays an important role in regulating the autonomic nervous system (ANS), which is responsible for maintaining a balanced internal environment. The reticular formation contains neuronal centers that manage various functions, such as controlling the heart rate and rate of respiration. It is also involved in regulating other basic functions such as digestion, salivation, perspiration, urination, and sexual arousal. The reticular formation and its connections constitute the reticular activating system (RAS), an arousal mechanism that keeps the brain alert and awake.

Regulation of Heart Rate
The heart rate is regulated by the hormonal action of the ANS, which, in turn, is regulated by the reticular formation. The sympathetic branch of the ANS speeds up the heart rate and the parasympathetic branch slows it down. The medulla in the brainstem contains a hub of neurons that constitute the cardioregulatory center, which, in response to information from the ANS, sends signals to the sinoatrial node and the atrioventricular node in the heart. These signals set the heartbeat according to the body's need for oxygen.

Regulation of breathing
The rate of breathing in and out is regulated by collections of neurons in the reticular formation, called the dorsal and ventral respiratory groups. These responds to levels of oxygen and carbon dioxide in the blood and regulate the breathing rate accordingly to maintain constant levels. The basal rate of breathing can also be adjusted (in response to increased activity or metabolism) through electrical impulses sent by the pontine respiratory center.

Functions of the Hypothalamus
The hypothalamus contains many minute clusters of neurons, called nuclei, which perform specific functions, including controlling body temperature, eating and drinking behavior, water balance, hormonal levels, and sleep-wake cycles. Among other things, the hypothalamus is regarded as the major coordinating center of the limbic system, and it has extensive connections with the pituitary gland and autonomic nervous system. Through these connections, it produces vital responses to body conditions and initiates feelings such as hunger, anger, and fear. The functions of the hypothalamus are essential to live, so even subtle damage can have dramatic effects on behavior and survival.

THE NEUROENGOCRINE SYSTEM (112-113)

Hormone Synthesis and Control
Glands are organs that respond to imbalances in the body in order to regulate internal activities, such as the absorption of nutrients, and influence activities such as the intake of food or water. They react by increasing or decreasing their production of hormones, which then travel to a target organ, where they lock onto specialized receptors on the surface of cells. This binding triggers a physiological change that restores homeostasis. The hypothalamus is the crucial link between the nervous system and endocrine system, releasing hormones that, in turn, trigger the pituitary gland to either stop or start secreting its hormones.

Hormones released by the pituitary gland	
Melanocye-stimulating hormone (MSH)	Stimulates the production and release of melanin, the determinant of skin and hair color
Adrenocorticotropic hormone (ACTH)	Triggers the adrenals to produce steroid hormones that control stress response
Thyroid-stimulating hormone (TSH)	Increases the activity of thyroid gland, which controls metabolism
Growth hormone (GH)	Acts on entire body, but especially important for growth and development in children
Luteinizing and follicile-stimulating hormone	Triggers the sex glands in males and females to make their own hormones
Oxytocin	Causes contractions during labor; also involved in the release of milk from the mammary glands
Prolactin	Stimulates the production of milk from the mammary glands
Antidiuretic hormone (ADH)	Controls amount of water removed from the blood by microfilters in the kidney

Feedback Mechanisms
Imbalances in the body are detected and corrected using feedback mechanisms, or loops. Levels or a hormone within the bloodstream are gauged and the information is sent to the control unit in charge of that hormone, which in most cases is the hypothalamus-pituitary unit. If the level of a hormone is high, the control unit responds by reducing the production of that hormone to achieve balance. If the level is low, the control unit initiates an increase in production. Feedback mechanisms are also used to rigger rare homeostatic functions, such as contractions during labor.

Hunger
The body maintains its weight at a set point by using hormones to trigger the sensations of either hunger or satiety. To stimulate the appetite, the stomach produces the hormone ghrelin, while fat tissues decrease their production of leptin and insulin. These changes signal to specific neurons […] to start producing more neuropeptide (NPY) and agouti-related peptide (AgRP), which stimulate eating. The production of these peptides also causes other neurons […] to inhibit the production of the hormone melanocortin, which usually works to suppress the appetite. These signals are transmitted to the lateral hypothalamic nuclei (via other neurons), which generates the sensation of hunger. To suppress the appetite, the body's fat tissues increase production of leptin and insulin. These hormones signal to neuron type B to inhibit production of NPY and AgRP. At the same time, the increased leptin and insulin trigger neuron type A to produce melanocortin. These signals reach the ventromedial nucleus in the hypothalamus, which creates the feeling of satiety.

Thirst

When the body's water levels fall, salt concentration increases and blood volume decreases. Pressure receptors in the cardiovascular system and salt-concentration-sensitive cells in the hypothalamus detect these changes. In response, the pituitary gland releases antidiuretic hormone (ADH), which acts on the kidneys to retain water and produce less urine. The kidneys secrete the enzyme renin into the blood which, through a series of reactions, forms the hormone angiotensin II. This is detected by the subfornical organs, which is connected to the hypothalamus, which in turn activates more ADH-producing cells and creates the sensation of thirst, leading to drinking.

Sleep-Wake Cycle

The suprachiasmatic nucleus (SCN) in the hypothalamus plays a key role in sleep-wake cycles. Light levels are sensed by the retina, and this information is relayed to the SCN, which then sends a signal to the pineal gland. This triggers the release of melatonin, the hormone that tells the body when to sleep. At this point, the brain becomes less alert and fatigue starts to take over. When melatonin levels fall in response to increased light, the waking part of the cycle begins.

PLANNING A MOVEMENT (114-115)

Conscious and Unconscious Movement

Many of our actions are conscious – thinking about picking up an object, for example, and then actually picking it up. However, there are many actions that take place without our awareness, such as blinking. Some unconscious actions may be triggered directly by environmental stimuli – the sight of food may trigger an automatic reaching movement, for example. Whether a complex movement is conscious or unconscious depends largely on the individual's level of skill. As an action becomes increasingly familiar, it can become "automatic." However, these movements can also be performed consciously if the individual turns attention to them.

Reflex Actions

Reflex actions are motor actions that are programmed into the spinal cord. The brain is not involved, and the actions cannot be controlled consciously. Most reflex actions protect the body by producing rapid reactions to escape from potentially damaging stimuli. In each case, the stimulus causes sensory nerve endings to fire; these signals pass through the nerve fibers to the spine, and trigger firing in the adjacent moor neurons, which then feed back to the relevant area and cause it to move.

Patellar Spinal Reflex

The "knee jerk" is a well-known example of a reflex action. It is used by doctors to test spinal-nerve function. Tapping the tendon just under the patella (kneecap) stretches the thigh muscle above, causing the lower leg to kick automatically.

Brain Areas and Movement

Both conscious and unconscious actions involve the primary motor cortex, which sends the "go" signals that contract the muscles (via the spinal cord and motor nerves). However, while unconscious movements are planned by areas in the parietal lobe, conscious actions involve "higher" frontal brain areas, including the premotor and supplementary motor cortices. They may also involve prefrontal areas, such as the dorsolatteral prefrontal cortex, where actions are consciously assessed. It may feel as though conscious actions result from a decision. In fact, unconscious areas of the brain plan and start to execute movements before we consciously decide to do them. The "decision" may, therefore, merely be the conscious recognition of what the unconscious mind is planning to do.

The Cerebellum

For the body to make any complex movement, the sequence and duration of each of its elements must be coordinated very precisely. This is controlled by the cerebellum, via a circuit that connects it to the motor cortex. It also modulates the signals that the motor cortex subsequently sends to the motor neurons. The cerebellum ensures that when one set of muscles initiates a movement, the opposing set acts as a brake, so that the body part in question arrives accurately at its target.

UNCONSCIOUS ACTION (118-119)
The brain registers events via the sense organs almost immediately, but it takes up to half a second to become conscious of them. In order to generate effective responses in a fast-changing environment, the brain must plan and execute moment-by-moment actions unconsciously.

Returning a Serve
Professional tennis players can plan and initiate the complex moves required to return a fast service before they are consciously aware that the ball is on its way. Unlike novice players, they do not have to think consciously about each muscle movement because practice has turned the relevant action sequences into automated motor programs that are stored and run unconsciously. Familiarity with their opponents' body language also allows them to make well-informed unconscious predictions about where the ball will land.

0 ms. Attention
The player's brain prepares for action by focusing attention on his opponent. This prevents the brain from responding to irrelevant stimuli and amplifies information coming from the part of the visual field containing the target of attention. If the player is familiar with the opponent's playing style, his brain will register the movements made by the opponent as he serves and compare them with previous observations to help predict where the ball will land. Attention to such cues may speed up reactions by 20-30 milliseconds.

70 milliseconds. Body Memory
The ball is not yet consciously visible to the player, but unconsciously his brain is already planning the actions he must make to return it. At this stage he is mainly using information about his opponent's movements to decide how his own body should move. A skilled player processes fewer visual cues than an inexperienced one because the brain identifies irrelevant signals at a very early stage and ignores them. The visual information from his opponent's movements activates the player's parietal cortex, which in turn calls up relevant procedural memories. These are learned – such as how to return a serve – that have become encoded as automatic motor programs. They are stored in an unconscious brain module called the putamen, which replays them as the situation demands.

250 milliseconds. Action Plan
The receiving player's brain brings together the information that has been registered so far to construct a response to the fast-approaching ball. The plan is informed by information gathered from the opponent's body movements, the (still unconscious) knowledge of the ball's speed and trajectory, and the procedural memories triggered by these stimuli. The plan is held in the premotor area, which lies just in front of the motor cortex. This is like a rehearsal stage, allowing action to be played out as a pattern of neuronal activity without affecting the muscles.

285 milliseconds. Conscious thought starts
The player's brain becomes consciously aware – belatedly – of the ball moving away from the opponent's racket. But his brain has already (unconsciously) predicted its real-time position, and – providing the two information streams do not clash – the player is likely to think he sees the ball where it really is.

355 milliseconds. Sending signals

The action plan held in the premotor cortex is transmitted to the neighboring motor cortex. The neurons in this strip of brain connect via the spine to skeletal muscles, and when they fire they cause the muscles to contract. In this case, the firing of neurons about halfway down the right side of the motor strip move the player's left arm and hand to position the racket to connect with the ball. Other neurons control the rest of the body. The sequence in which these neurons fire – and therefore the sequence of limb movement – is controlled by the cerebellum.

500 milliseconds. Conscious Act
If the player's conscious perception of the ball's trajectory differs markedly from his earlier, unconscious prediction he may veto the earlier action plan and start to construct an alternative, or try to adjust the current plan to take into account the new information. It takes another 200-300 ms, however, to incorporate the new, conscious information into a revised action plan and by then the ball has traveled too far for any player to be able to return it.
The situation is similar to the one that occurs when a person steps forward onto what the brain predicted was flat ground, but which is actually a downward step. The resultant physical catastrophe, in both cases, triggers a further cascade of signals that may generate a wide range of emotions, including anger, embarrassment, and a feeling of failure.

MIRROR NEURONS (120-121)
Certain neurons are activated when you move, and also when you see someone else moving. This means we unconsciously mimic the actions of others, and thus share, to some extent, their experience. Mirror neurons also allow us to know what another person is feeling, without having to think about it. These findings are among the most significant neuroscientific discoveries in recent years.

What Are They?
Mirror neurons were first discovered in the motor-planning area in the brains of macaques (a species of monkey) and subsequent brain-imaging studies suggest that they exist in humans too. The human mirror system seems to be broader in scope than that of monkeys, in that mirror neurons exist not only in movement areas, but also in areas concerned with emotions, sensations, and even intentions. They provide people with immediate knowledge of what is going on in another's mind; this ability to know what another person is feeling or doing is thought to be the basis of mimicry.

Mirroring Touch
Mirror neurons also seem to operate in the somatosensory cortex – the area of the brain that registers touch. In one study, subject's brains were scanned, first while their leg was brushed, and then while they watched a video of someone else's leg being touched. Activity in their brains revealed that some parts of the somatosensory areas are activated only by direct touch and others are activated by the sight of another being touched. A third group of neurons, however, are activated both by direct touch and by seeing others being touched. These mirror neurons […] were limited to the left hemisphere in this study, though in other experiments they have been detected in both hemispheres.

Mirroring Emotions
When one person sees another expressing an emotion, the areas of the brain that are associated with feeling that emotions are activated, making emotions transmittable. In one study, volunteers inhaled a disgusting smell, and later, watched a video of someone else smelling something and expressing disgust. Both produced neuronal activity in the area of the brain associated with feeling disgust. Emotion mirroring is thought to be the basis of empathy. Autistic people, who tend to lack empathy, have been found to show less mirror-neuron activity.

Mirroring Intentions

Two movements may be identical, but may signal very different things in different contexts. Human mirror neurons seem to take this into account. When one person sees another picking up a cup in order to drink from it, a different set of neurons are activated from those that light up at the sight of a person making the identical movement but in a context that suggests they are clearing the cup away. Hence, the observer's brain does not just generate a faint idea of what the other person is doing with their body, but also an echo of their intention in doing it. This allows us to get a glimpse of another individual's plans and thought processes without consciously having to work it out.

EMOTIONS AND FEELINGS

THE EMOTIONAL BRAIN (124-125)
Emotions may seem to be conscious feelings, but they are, in fact, "inner motions" - physiological responses to stimuli, designed to push us away from danger and toward reward. Emotions are generated constantly, but much of the time we are unaware of them.

Amygdala
The amygdala "tastes" all stimuli and signals other areas to produce appropriate emotional reactions. It contains distinct regions called nuclei, which generate different kinds of responses to fear. The central nucleus generates the fear response of freezing, while the basal nucleus generates the fear response of flight. The nuclei are affected by sex hormones, and are therefore different in men and women. Activation of the amygdala can be modulated by the hypothalamus.

Positive Emotions
Limbic system structures next to the amygdala are involved in feelings of pleasure, mainly by reducing activity in the amygdala and in cortical areas concerned with anxiety. Anticipation and pleasure-seeking are influenced by the "reward" circuit. This acts on the hypothalamus and amygdala: it secretes dopamine, which provides anticipation and drive, and GABA, which inhibits neurons from firing.

Unconscious Emotions
We have evolved a conscious emotional system, but we retain the primitive, automatic responses at the heart of emotions. A frightening sight or sound, for example, registers in the amygdala before we are even conscious of it. While the sensory information is sent to the cortex to be made conscious, the amygdala sends messages to the hypothalamus, which triggers changes that ready the body for flight, fight, or appeasement. This "quick and dirty" route allows us to take instant action to save ourselves. When we "start" at a loud noise, then relax on realizing that it is harmless, we are experiencing both stages – unconscious reaction and conscious response.

Feeling Fear
The amygdala acts as a store for good and bad memories, especially emotional traumas. It is also "hard-wired" to fear certain stimuli, such as low-fling birds, spiders, and snakes. For a phobia to develop, however, there also needs to be an environmental trigger, such as a nasty encounter with a "hard-wired" stimulus, or the sight of someone else being frightened by it. It is often very hard to get rid of a phobia because the amygdala is not under conscious control. It can, however, "learn" to reduce its reaction to the stimulus.

CONSCIOUS EMOTION (126-127)

Feeling Emotion
Emotions are primarily unconscious physical reactions to threat or opportunity. The sight of a snake, for example, automatically prepares the body for flight. In humans, emotions are consciously experienced as powerful "feelings" that give our lives meaning and value. The

unconscious physiological component of emotion is generated in deep brain areas as signals that are then sent to the body to prepare it for action. Some signals travel upward to activate cortical areas, and this activation produces the feeling of emotion. The type of emotion experienced depends on which parts of the cortical areas are activated.

Emotion Circuits

Information from the environment, and from the rest of the body, is constantly "tasted" for emotional content. The main emotion "sensor" is the amygdala, which is particularly sensitive to threat and loss. The amygdala takes in information both directly from the sense organs and via the sensory cortices, and connects to the cortex and also to the hypothalamus, creating a circuit. When the amygdala is activated, it sends signals around the circuit. These trigger body changes as they pass through the hypothalamus, and create conscious recognition of the emotion as they pass through the frontal lobe. Positive emotions are passed along a slightly separate circuit, which takes in an area of the brainstem that produces the mood-lifting neurotransmitter dopamine.

Timing Emotion

Things that we find emotionally moving grab our attention rapidly compared with things that we do not. The sight of something that poses a threat, for example, is brought to conscious awareness faster than a nonemotional stimulus. This may be because the amygdala unconsciously picks p the threat and primes the conscious brain to "expect" an important perception. Good things also attract attention fast. Research shows that people react as quickly to an image of a smiling baby as they do to one of angry face – both elicit quicker reactions than nonemotional stimuli.

Less Than 100 milliseconds. Initial awareness

Responses to emotional visual stimuli can travel unless than one-tenth of a second from the superior colliculus in the brainstem to the frontal cortex, where the emotion is consciously experienced.

100-200 milliseconds. Further Information

A little later, information comes in from the sensory cortices and association areas – such as the face-recognition area in the fusiform gyrus – providing more detailed input to emotion-inducing parts of the brain, such as the amygdala.

350 milliseconds. Full Awareness

After about 350 milliseconds, the emotional meaning of a stimulus has been evaluated by the brain. Signals from the amygdala trigger a conscious response in the body, which in turn feeds back to areas such as the insula.

Emotions and Moods

An emotion is usually transient and arises in response to the thoughts, activities, and social situations of the day. Emotions act as cues that prompt adaptive behavior. Moods, in contrast, may last for hours, days, or even months, in the case of some illness. Thus, the emotional state of distress, when extended over time, is called sadness; if it persists, unrelenting, for a period of weeks, it is referred to as depression. Moods can be initiated very quickly by things that we are not even aware of. One study, for instance, found that flashing pictures of a disgusting nature for a split second – too fast to be seen consciously – made those who were subjected to them more sensitive to other stimuli of a similar nature afterwards. The feelings elicited by these unconscious stimuli were described by the volunteers as "moods" rather than emotions.

DESIRE AND REWARD (128)

Desire

Desire is a complex drive that strongly reflects personal preferences. It is made up of two different components – liking and wanting. Put simply, liking is linked to getting pleasure, while wanting is linked to an actual need for something. With some activities, such as eating, sleeping, and sexual activity, liking and wanting overlap, and the resulting desire has survival value. However, an individual with an addiction may want and "need" a drug, but not particularly like or enjoy it, so the resulting pleasure is tainted with destruction. Liking and wanting seem to use somewhat different brain circuits, although dopamine is the most important neurotransmitter in both cases.

Pleasure-Seeking and Addiction
Addictive substances can activate the dopamine reward system, providing pleasure, even though the substances are not essential to survival. Chronic exposure to drugs leads to the suppression of reward circuits, increasing the amounts needed to get the same effect. The opiate system is involved in pain and anxiety relief. Heroin and morphine lock onto the opiate receptors, creating a sense of euphoria. The cholinergic circuits – where nicotine acts – are involved in memory and learning. Cocaine acts at the noradrenergic receptors, which are involved in stress responses and anxiety.

Anticipation
Learning and memory clearly play an important role in shaping desires and preferences. This leads to the possibility of anticipation, which is the expectation of a reward. Anticipation has been studied by researchers using a game of chance. In the anticipation phase, where participants were told they might win money, fMRI scans showed the cerebral blood flow in the amygdala and orbitofrontal cortex increased, indicating activity in the nucleus accumbens and the hypothalamus – all rich in dopamine receptors. The bigger the potential reward, the greater the brain activity.

THE SOCIAL BRAIN

SEX, LOVE AND SURVIVAL (132-133)

Different Types of Love
Love is a complex phenomenon, encompassing sex, friendship, intimacy, and commitment. Not only does it have a survival value for the individual as well as the species, it also adds greatly to quality of life. As far as sex is concerned, humans engage in it whenever they wish, unlike most other species who undertake sex only when the female is ready to conceive. Therefore, sex has become disconnected from reproduction in humans. Romantic love, which is what many people mean by "love," has a survival advantage because it promotes pair bonding – an ideal setting for the care and protection of young children. Friendship and social networks are also important for promoting health and well-being. We know a little about the neurotransmitters involved in "falling in love," but not much about corresponding brain circuits. Phenylethylamine and dopamine are involved in the initial euphoria, which probably act in the pathways between the limbic system (concerned largely with emotions) and cortical areas (concerned with reason).

Sexual Attraction
An individual's face is an important element in how attractive they appear to others and whether they are instinctively considered a good mating prospect. The degree of symmetry, which is linked to how masculine or feminine they appear, has been shown to be an important aspect of facial attractiveness. A recent study shows that these properties are involved in sexual pairings in groups of Europeans, African hunter-gatherers, and one group of nonhuman primates. Because the relationship is common to two human groups and one primate groups, it may be universal. It seems, therefore, that symmetry and how masculine or feminine a face appears are linked to an underlying biological mechanism that could advertise a person's level of attractiveness and genetic fitness as a mate.

Oxytocin – The Feel-Good Factor
Oxytocin is a hormone produced by the hypothalamus and released by stimulation of the sex and reproductive organs, during orgasm and in the final stages of childbirth. It produces a pleasurable feeling that promotes bonding. This could be because, like the closely related hormone vassopressin, oxytocin helps the processing of social cues involved in the recognition of individuals, and may play a role in laying down shared memories. It is possible that oxytocin has a somewhat "addictive" effect, like dopamine. This may explain why people feel anguish at being parted from loved ones – they miss the oxytocin "rush" involved in being with them.

Attachment
Humans form attachments – bonds of intimacy and affection – with people, animals, and objects. The importance of attachment was underlined by the observation of babies in orphanages during World Wars I and II. They were provided with food and shelter, but not the care and attention of a parent. Many experienced long-term problems: they did not gain weight, became emotionally and physically stunted, or simply died. They were not held, smiled at, kissed, or talked to, so no attachments could form. A mother's instinct to bond with her baby appears to be built into the brain. Imaging studies have shown that when a woman sees a picture of her own baby smiling, it triggers strong activity in the dopamine reward system. Of her brain. Pictures of other babies smiling produces a weaker response here, but crying or neutral expressions in the mother's own babies did not activate the system at all.

EXPRESSION (134-135)

Expressing Emotions
Expressions are more than just signals, they are an extensions of the emotion itself. When we feel something, the neural activation pattern associated with the emotion includes the firing of neurons which, if not inhibited, cause face and body muscles to contract in characteristic ways. There are six basic, or universal emotions [surprise, anger, disgust, fear, happiness, sadness]. Recent studies have looked at the range of expressions used by people who have been blind since birth and found that they are similar or identical to those displayed by sighted people. This suggests that learning plays quite a small part in expression.

Babies and Pets
One way that expressions work to our advantage is that we can use them to manipulate others. The need to persuade other people to behave in ways that benefit us is greatest among those who are powerless. This is probably why babies are born with a range of facial and aural expressions, such as gurgling and crying. These help the babies get what they want or need in the way of attention and food. Typical pet animals, such as dogs and cats, also have expressions that we read and respond to. The most popular pets tend to be those that best mimic human expressions.

Anatomy of a Smile
There are two fairly distinct types of human smile: the conscious "social" smile, and the genuine "Duchenne" smile, which is named after the French neurologist Guillame Duchenne, who first described it. The first involves consciously activating the muscles that stretch the mouth sideways. The second involves an additional set of muscles, which are mainly controlled by unconscious brain processes. These muscles make the lower lids of the eyes swell and the edges crinkle into "crow's feet." Expressions not only show what a person is feeling, they can also actually bring about the feeling that they are associated with. In laboratory tests, consciously producing a smile was found to produce a weak, but detectable, sense of happiness in those who displayed it. So, even producing a "fake" social smile can promote a faint but real sensation of happiness in the person expressing it.

Reading Emotions

When we read somebody's expression, we automatically make it ourselves. We an hide this echo by consciously inhibit the muscular change. Because expressions cause, as well as transmit, our feelings this mimicry creates an echo of the emotion we see and tell us how the other person is feeling. This is shown by experiments in which people are stopped from echoing expressions by temporarily paralyzing an area of the motor cortex with transcranial magnetic stimulation. When volunteers were unable to mimic expressions, they were less accurate at reading them in others.

Conflicting Emotions
Expressions have a direct effect on those who see them, so they are useful to get others to serve our needs. However, in social situations we sometimes have to make a conscious effort to stop making the expression that matches either what we spontaneously feel or what we see in others. Because expressing an emotion creates that emotion, when we do this we have to override one emotion with another, creating emotional conflict. Humans are probably unique in using facial expressions dishonestly, and we have become experts at doing so, but we are also very good at scrutinizing the expressions of others to discern the genuine from the fake.

THE SELF AND OTHERS (136-137)

Made to Be Sociable
One of the most distinctive features of the human brain is the large area of neocortex, its relatively recently developed outer layer. The frontal cortex (the part of the neocortex that surrounds the frontal lobe) is responsible for abstract reasoning, conscious thought and emotion, planning, and organization, and is highly developed in humans. One reason for the substantial growth of the neocortex may be that humans adapted this way in response to the demands of living in large, close-knit groups. Social living creates challenges such as moderating one's own behavior in order to accommodate others, competing subtly for reproductive rights, and predicting how others will behave, all of which require neocortical activity.

Social Awareness
Social awareness covers a wide range of cognition that generates a sense of a “self” as well as of that self in a social context. For example, we adapt our behavior to cooperate with others, we predict what other people are likely to do and their reasons for doing it, we understand that others ma hold different ideas and beliefs from our own, we are able to imagine how other people see us, and we can scrutinize our own minds. The range and diversity of skills required means that several areas of the brain are involved.

The Insula
The insula may be responsible for humans experiencing the feeling of a “self” and having a sense of the boundary of that self, allowing for the distinction between “me” and “you.” According to a school of thought known as “embodied cognition,” which proposes that rational thought cannot be separated from emotions and their impact on the body, the insula detects body states that are induced by emotions as part of a process that brings our emotional experiences into our consciousness.

The Pain of Rejection
In one study, fMRI scans were conducted on people playing a virtual ball game from which they were progressively excluded. Upon awareness of rejection, the anterior cingulate (ACC) was activated, an area that also registers body pain, suggesting that the emotional impact of the two is similar. Part of the prefrontal cortex that helps control emotions was also activated, which seemed to reduce feelings of rejection.

Congruence

Our rains are highly sensitive to the movements of other animals, especially other humans. The mirror neuron system automatically makes us mirror the actions of others. The effect is so strong that when one person notices another not mirroring their own actions, it often makes them falter in their own actions. This "interference effect" applies only to biological motion – when participants observe a robot, no such interference occurs, even if the actions are humanlike.

Responding to Emotion
Facial expression is a signal – of intentional and state of mind – and also a means of achieving empathy between people. Expressions are initially processed unconsciously by the amygdala, which monitors incoming data for emotional content. It responds by generating the emotion that has been observed. A fearful expression, for example, produces amygdala activation that triggers fear in the observer. Soon after the amygdala activation, the expression registers in the face-recognition area situated in the fusiform gyrus. Studies suggest that if a face expresses emotion, the amygdala signals this area to scrutinize it for meaning.

Theory of Mind
Theory of mind (ToM) refers to the instinctive "knowledge" that other people may hold different beliefs that one's own, and that it is those beliefs, not the fact of a situation, that inform and determine their behavior. One way to test for ToM is the Sally-Ann test. Recent studies have shown that infants as young as 10 months may "pass" the Sally-Ann test.

Autism and the Mind
Autism is marked by the absence of ToM. Rather than just "knowing" why Sally acts according to a false belief, people with Asperger's syndrome (a form of autism) consciously "work out" what is happening using part of the brain that is thought to be more recently evolved than the area that generates ToM.

THE MORAL BRAIN (138-139)

Empathy and Sympathy
"Feeling" for another person – experiencing a faint version of their sorrow or flinching when you see them hurt – seems to be largely instinctive. It depends partly on ToM, which ensures that we "know" what is likely to be going on in other people's minds. Empathy goes a step further, in that it also involves "echoing" the emotions of another person. When a person is told a story about someone experiencing emotional trauma, the activated areas in the listener's brain come into play when he or she is in such a situation.

Morality
Our sense of right and wrong permeates all our social perceptions and interactions. Moral decision-making is partly learned, but it also depends on emotions, which give "value" to actions and experiences. When making moral judgments, two overlapping but distinct brain circuits come into play. One is a "rational"circuit, which weighs up the pros and cons of an action objectively. The other circuit is emotional. It generates a fast and instinctive sense of what is right and wrong. The two circuits do not always arrive at the same conclusion, because emotions are biased toward self-survival and/or protecting those who are loved or related to oneself. Emotional bias in moral judgments seems to rely on activity in the ventromedial and orbitofrontal prefrontal cortex. Studies of people with damage to this area have found that their moral judgments are more rational than those of others, suggesting that human "morality" is hard-wired into the brain, and evolved more to protect ourselves than to "do good."

Altruism
The notion that altruism assumes that people can do things for others with no motivation of a direct reward form themselves. However, brain scans show that doing "good" things is personally

rewarding. One fMRI study was conducted while participants made or withheld donations to real charities. The participants could keep any donations they refused to make. The result showed that both keeping the money and giving it away activated the brain's "reward" pathways. Giving away money also enhanced activity in areas concerned with belonging and group bonding.

Phineas Gage
The idea that our moral sense may have a biological basis in the brain arose largely as a result of a freak accident in 1848. A well-respected rail worker called Phineas Gage blew a hole in the front of his brain with a tamping rod that he was using to compress explosive powder. He survived with remarkably little damage to most of his faculties. His behavior, however, changed dramatically. From being a conscientious, polite, and thoughtful man he became reckless, rude, and socially irresponsible. Acquaintances remarked that he was "no longer Gage." The change was linked by his doctor to his brain damage, and modern reconstructions of the injury show that it affected the areas now known to be central to moral sensitivity.

Morality Versus Rationality
The two cognitive circuits that generate moral judgments do not always arrive at the same conclusion. The one that engages emotions almost certainly evolved first, in an environment in which survival depended on protecting tribal units rather than adhering to a social code that includes, for example, the right to justice and equal rights. Hence the instinctive, or "natural," judgments we make may vary from those we arrive at after consideration. For example, we tend to help people who are close or similar to us more than those who are distant and strange.

Conflicting Moral Values	
Natural Morality	Rational Morality
Favor those nearest and most similar to self	Treat all people in same way
Judge positive acts, for example, murder more harshly than acts of omission, for example, failing to intervene in a murder	Judge by result of action/inaction rather than by whether the act is active or passive
Less concerned about acts of violence that involve causing pain at a distance, for example, less inhibited about killing by launching missiles than killing by hand-to-hand combat	Judges acts involving local and distant consequences as equal

Psychopaths and Bullies
Psychopaths are defined as people who use manipulation, intimidation, and violence to control others and satisfy selfish needs. They display an inability to feel guilt, remorse, or anxiety about their antisocial behavior. This may result from damage or developmental problems involving the moral circuits of the brain. Imaging studies have found that psychopaths show low levels of activity in the amygdala when faced with stimuli that would be emotionally traumatic to others and normally generate amygdala activation.

LANGUAGE AND COMMUNICATION

THE ORIGINS OF LANGUAGE (144-145)

Hemisphere Specialization
Compared to the brains of other species, human brains are less symmetrical in terms of functions. Language is the most obvious example of this lopsidedness, and the vast majority of people have the main language areas on the left side of the brain, although a few seem to have language functions distributed on both sides, and some have it only on the right. Generally, language is associated with the "dominant" side of the brain – that is, the one that controls the most

competent hand. Language is thought by some to be the mechanism that elevates the brain to full consciousness, and before language evolved it is possible that our ancestors were not consciously aware of themselves. Because language is so important, disruptions have awful consequences, so brain surgeons have to be very careful to avoid damaging the language areas. This is one of the reasons for the Wada test.

The Wada Test
The Wada test, named after Canadian neurologist John Wada, involves anesthetizing one hemisphere of the brain while leaving the other fully active. This is possible because each hemisphere of the brain has its own blood supply. If the patient is able to speak when one brain hemisphere is asleep, the principal language areas must be on the conscious side. This information is vital for surgeons to plan operations. The Wada test will eventually be replaced y advanced scanning techniques.

Silbo Language
Most languages use words – that is, noises made by exercising muscles in the throat and mouth that chop up (articulate) and vary the sound of the passage of air from the lungs. Silbo, however, is a language made up entirely of whistles, used by the inhabitants of La Gomera in the Canary Islands. Brain-imaging studies show that Silbo-users process the whistles in the main language areas of their brains, whereas those who do not know the language process the whistles simply as a collection of sounds, which are registered in other areas of the brain.

What is Language?
Language is not just a matter of stringing symbols together to convey meaning. Language is governed by a complex set of rules, known as grammar. The details of these rules differ from language to language, but they share a similar type of complexity. Simple, wordlike sounds do not engage language areas in the same way that words that form part of a language do – the brain just treats them as noises. Some theorists believe that the overarching rules of language – the structure that is common to them all – is embedded in the human brain and is instinctive rather than learned. Although primates have learned how t link visual symbols on keyboards to objects and some can understand sign language, it has not been possible to teach another species spoken language.

Language and Perception
Language is much more than just a way of signaling things to one another – evidence shows that it shapes the way we perceive the world. If your language makes a distinction between blue and green, for example, you will be less likely to confuse a blue color chip with a green one when recalling them, because you will have been able to attach a mental label to each of them. If a language does not distinguish between colors in the same way, it will be more difficult to recall which is which. Similarly the Amazonian Piraha tribe do not have words for numbers above two, and are unable to reliably tell the difference between four and five objects placed in a row.

The Evolution of Language
Spoken language leaves no traces in the historic record, so we shall probably never know how or even exactly when it originated. The ability to generate speech and understand language is something only humans possess, although some primates' brains have regions that may function as primitive language areas. An important factor in the evolution of language took place in the thorax and larynx, around the time that our ancestors started walking upright. These changes affected the variety and intricacy of the sounds they could produce. This improved ability to communicate probably increased the chances of survival for those who used it most effectively and therefore the chances of it being passed on to subsequent generations.

THE LANGUAGE AREAS (146-147)

Main Language Areas

Language processing occurs mainly in Broca's and Wernicke's areas. Broadly speaking, words are comprehended by Wernicke's area and articulated by Broca's. A thick band of tissue called the arcuate fasciculus connects these two areas. Wernicke's area is surrounded by an area known as Geschwind's territory. When a person hears words spoken, Wernicke's area matches the sounds to their meaning, and special neurons in Geschwind's territory are thought to assist by combining the many different properties of words (sound, sight, and meaning) to provide full comprehension. When a person speaks, the process happens in reverse: Wernicke's area finds the correct words to match the thought that is to be expressed. The chosen words then pass to Broca's area via the arcuate fasciculus (or, possibly, via a more circuitous route through Geschwind's territory). Broca's area then turns the words into sounds by moving the tongue, mouth, and jaw into the required position and by activating the larynx.

Language Tasks

Different types of language tasks activate a number of different areas of the brain. However, the key language areas only become active when language is turned into meaning. So merely looking at words as marks on a page involves areas of the brain such as the visual cortex, which is responsible for processing incoming visual information, whereas listening to spoken words triggers activity in Wernicke's area and Geschwinds's territory, signifying that the sounds are being turned into meaningful information. Broca's area is significantly involved in listening, too, because understanding words involves, to some extent, articulating them "in your head" (also referred to as "sounding out"). Broca's area is strongly activated when the task involves pronouncing words, while generating words involves both Wernicke's and Broca's areas, as well as Geschwind's territory.

The Multilingual Brain

Being fluent in two languages, particularly from early childhood, enhances various cognitive skills and might also protect against the onset of dementia and other age-related cognitive decline. One reason for this may be that speaking language builds more connections between neurons. Studies show that bilingual adults have denser gray matter, especially in the inferior frontal cortex of the brain's left hemisphere, where most language and communication skills are controlled. The increased density was most pronounced in people who learned a second language before the age of five.

Language Problems

There are a wide range of speech and language problems that can arise from a correspondingly varied number of injuries and impairments. Some problems only affect comprehension, whereas others specifically hinder expression; learning disabilities, such as dyslexia and specific language impairment can affect both. Traumatic brain injuries and strokes can lead to aphasia, which is the loss of the ability to produce and/or comprehend language. By contrast, dysphasia is the partial loss of the ability to communicate, although these terms are often incorrectly used interchangeably.

Stuttering

About 1 percent of people (75 percent of them men) stutter. In most cases, stuttering (also known as stammering) begins between the ages of two and six. Imaging studies have shown that the brains of stutterers behave differently from those of non-stutterers when processing speech, in that many more areas of the brain are activated during speech production. It may be that these interfere with one another and cause the stuttering, or it may be the result of stuttering.

Types of Aphasia

Aphasia is usually associated with a brain injury (such as a stroke), which affects the brain's language areas. Depending on the type of damage, the area affected, and the extent of damage, those suffering from aphasia may be able to speak, yet have little or no comprehension of what they or others are saying. Or they may be able to understand language, yet be unable to speak. Sometimes, sufferers can sing but not speak, or white but not read.

Production aphasia (damage to Broca's area) Inability to articulate words or string them together; if words can be uttered, they tend to be verbs or nouns, with abnormal tone and rhythm.

Global aphasia (widespread damage) General deficit in comprehension, repetition, naming, and speech production; automatic phrases (e.g. reeling off numbers) may be spared.

Transcortical motor aphasia (damage around Broca's) Good comprehension but nonfluent speech, often limited to two words at a time. Sufferers retain the ability to repeat words and phrases.

Conduction aphasia (damage to link between Wernicke's and Broca's areas) Speech errors include substituting sounds, but good comprehension and fluent speech production.

Transcortical sensory aphasia (damage to temporal-occipital-parietal junction) Inability to comprehend, name, read, or write, but with normal ability to recite previously learned passages.

Sensory aphasia (damage to Wernicke's area) Inability to understand language, often combined with general comprehension problems and lack of awareness of own deficit.

A CONVERSATION (148-149)

Listening

The sound of spoken words take a short time – about 150 milliseconds – to pass from the speaker's mouth to the listener's ear, for the ear to turn this stimulus into electrical signals, and for this to be processed as sound by the auditory cortex. Words are decoded in Wernicke's area in the left hemisphere, but other areas are also at work to provide full comprehension, including parts of the right hemisphere concerned with tine, body language, and rhythm. If any of these areas are damaged, a person may be left with an incomplete understanding of what is being communicated.

50-150 milliseconds. After Words Are Spoken. Sound Registered

Sound from the speakers registers in the auditory cortex and is distributed to areas concerned with decoding the words and other areas of the brain involved with emotion, tone and rhythm.

150-200 milliseconds. Emotional Tone Registered

The amygdala is quick to pick up on the emotional tone of the speech and subsequently produces an appropriate emotional reaction

250-350 milliseconds. Structure of words Stream Analyzed and Meaning of Words Extracted

Speech is decoded in Wernicke's area in the left hemisphere. Then, the anterior temporal lobe and interior frontal cortex in both hemispheres start to extract the meaning of the words.

400-550 milliseconds. Meaning consciously Comprehended

Turning the sound of speech into a stream of meaning requires more than just decoding the words – they also have to be associated with memories to give full comprehension. This takes place in part of the frontal lobe.

Speaking

The speech process starts about a quarter of a second before words area actually uttered. This is when the brain starts to select the words that are to convey whatever the person wants to say. The words then have to be tuned into sounds, and are finally articulated. Most of this complicated activity occurs in specific language areas, which in most people are on left side of the brain. However, in a minority of people they are situated in the right, or spread between both hemispheres. Right-hemisphere language dominance is more prevalent among left-handers.

-250 milliseconds. Before Speaking. Concepts to Words
Words are attached to memories and ideas and act as "handles" by which the brain can grasp the correct ones to express an idea. The matching of words to concepts happens in the temporal lobe.

-200 milliseconds. Words to Phonology
Shortly after they have been retrieved from memory, the words are matched to the sounds in Wernicke's area, which is adjacent to the auditory cortex, where sounds are distinguished.

-150 milliseconds. Phonology to Syllables
Broca's area is the part of the brain most closely associated with speech. It matches the sounds of words to the specific mouth, tongue, and throat movements required to actually voice them.

-100 milliseconds. Articulation
The mouth, tongue and throat movements needed to articulate the selected words are directed by the part of the motor cortex that controls these parts of the body.

under 100 milliseconds. Fine Control of Articulation
The cerebellum is concerned with orchestrating the timing of speech production. The right cerebellar hemisphere connects to the left cerebral hemisphere, and this shows greatest activation during speech, whereas the left cerebellar hemisphere is more active during singing.

READING AND WRITING (150-151)

Learning to Read and Write
To learn how to read and write, a child has to translate the shapes of letters on the page into the sounds they make if they are spoken aloud. The word "cat," for instance, must be broken down into its phonological components - "kuh," "aah," and "tuh." Only when the words on the page is translated into the sound that is heard when the word is spoken, can the child match it to its meaning. Learning to write uses even more of the brain. In addition to the language areas concerned with comprehension, and the visual areas concerned with decoding text, writing involves integrating the activity in these areas with those concerned with manual dexterity, including the cerebellum, which is involved with intricate hand movements.

Skilled Readers
While we are learning to read, our brains have to work very hard to translate the symbols on the page into sounds. This activates an area in the upper rear of the temporal lobe, in which sounds and vision are brought together. The process becomes automatic with practice, and the brain becomes more concerned with the meaning of the words. Hence, the areas concerned with meaning are more active in a skilled reader's brain (usually an adult's) during reading.

How Literacy Affects The Brain
Literacy may improve the ability to make fine distinctions between spoken sounds. Tests have shown that when literate people hear a spoken sound they don to recognize as a word, a wider network of brain areas becomes active than in those who cannot read or write. This enables them to compare the unknown word with a greater number of possible matches, as they hear the word's phonological components more accurately.

Reading in Your Mother Tongue
Languages are stored in separate areas in the brains of bilingual people, which means that different groups of neurons are used to generate each language. This prevents the two languages from interfering with one another. Damage to one area of the brain can result in the complete loss of one language, while the other remains intact. The brain treats a second language learned later

in life differently from the mother tongue. A language that has been absorbed from infancy has wider and more intense associations than a second language, so the brain is more active when the person reads in the mother tongue than in any other language.

Dyslexia
Dyslexia is a language-development disorder with a genetic basis. It may affect 5 percent of the population, and is most obvious when a language such as English, has a complex mapping system between speech sounds and letters of the alphabet. One explanation for dyslexia, known as the phonological deficit hypothesis, is that dyslexics cannot analyze and remember the sounds contained in words. This slows down the learning of spoken language and makes it very difficult to map sounds to their corresponding letters of the alphabet when learning to read.

Language Differences
English speakers have a particularly hard time learning to read. English spelling rules are notoriously difficult to master, and skilled readers know that they cannot rely on letter-to-sound decoding rules, as there are too many exceptions – for example, "i" is pronounced differently in "ice" and "ink." for dyslexics, these exceptions are difficult to master, and learning to read and spell takes years longer than it does for non-dyslexics.

English-Speaking Dyslexics
Learning to read English can be challenging for dyslexics due to the number of words that do not follow standard spelling rules.

Italian-Speaking Dyslexics
Italian dyslexics are more accurate at word recognition than their English counterparts, as Italian spelling rules are less complex.

MEMORY

THE PRINCIPLES OF MEMORY (154-155)

What is Memory?
A memory may be the ability to recall a poem or recognize a face on demand; a vague vision of some long past event; the skill required to ride a bike; or the knowledge that your car keys are on the table. What all these phenomena have in common is that they involve learning, and total or partial reconstruction of a past experience.
Learning is a process in which neurons that fire together to produce a particular experience are altered so that they have a tendency to fire together. The subsequent combined firing of the neurons reconstructs the original experience, producing a "recollection" of it. The act of recollecting makes the neurons involved even more likely to fire again in the future, so repeatedly reconstructing an event makes it increasingly easy to recall.

Short- and Long-term Memory
Short-term memories generally stay with us only as long as we need them. A telephone number you use just once is an example. Short-term memories are held in the mind by a process of "working" memory. Longer-term memories, in contrast, can be recalled years or even decades later. The address of your childhood home may be such a memory. In between these extremes, we have many medium-term memories, which may last for months or years and finally fade away.
Many different factors determine whether an experience or item of knowledge is destined to be a short- or a longer-term memory. These include their emotional content, novelty, and the amount of effort that we make to practice recalling them.

Memory Process		
The process of memory formation has several natural stages, from the initial selection and retention of information to recollection and, sometimes, eventual change or loss of the memory. Each stage has particular characteristics – and things that can go wrong.		
Stage	**What's Meant to Happen**	**What Can Go Wrong**
Selection	The brain is designed to store information that will be useful at a later date and allow the rest to pass by unnoticed	Important events are neglected or irrelevant ones retrieved. You might fail to recall a person's name, but remember the mole on their nose
Lay-down	Experience selected for memorizing is stored so that it is associated with relevant pre-existing memories and retained for an appropriate period	Information may be "mis-filed," with faulty links between items. Or new items are not laid down, so it is hard to learn or to retain new memories
Recollection	Current events should stimulate the recollection of appropriate memories – i.e. information that can guide future actions	Current events fail to prompt useful memories, such as words, names, events – you know the information is there but you cannot grasp it
Change	Each time a memory is recalled it is altered slightly to accommodate new information	Alteration may create false memories
Forgetting	Items start to be forgotten as soon as they have been registered, unless they are regularly refreshed. Unnecessary information is deleted	Important or useful information is forgotten. Alternatively, unnecessary or even damaging memories are not

Types of Memory

We have five different types of memory, for particular purposes. <u>Episodic memory</u> comprises reconstructions of past experiences, including sensations and emotions; these usually unfold like a movie and are experienced from one's own point of view. <u>Semantic memory</u> is non-personal, factual knowledge that "stands alone." <u>Working memory</u> is the capacity to hold information in mind for just long enough to use it. Procedural <u>"body" memories</u> comprise learned actions, such as walking, swimming, or riding a bicycle. <u>Implicit memories</u> are those we don't know we have. They affect our actions in subtle ways; for example, you might take an inexplicable dislike to a new person because they remind you of some one nasty.

THE MEMORY WEB (156-157)

Brain-Wide Web

"Declarative" memories – episodes and facts you can bring to mind consciously – are laid down and accessed by the hippocampus but are stored throughout the brain. Each element of a memory – the sight, sound, word, or emotion that it consists of – is encoded in the same part of the brain that originally created that fragment. When you recall the experience, you recreate it in essence by reactivating the neural patterns generated during the original experience that was encoded to memory. Take, for example, the memory of a dog you once owned. Your recall of his color is created by the "color" area of the visual cortex; the recollection of walking with him is reconstructed (in part at least) by the motor area of your brain; his name is stored in the language area, and so on.

Forming Memories

The initial perception of an experience is generated by a subset of neurons firing together. Synchronous firing makes the neurons involved more inclined to fire together again in the future, a tendency known as "potentiation," which recreates the original experience. If the same neurons fire together often, they eventually become permanently sensitized to each other, so that if one fires, the others do as well. This is known as "long-term potentiation."

Distributed Memories
Our memories are distributed throughout the brain, so even if one part of an experience is lost, many others will remain. One benefit of such a distributed storage system is that it makes long-term memories more or less indestructible. If they were held in a single brain area, damage to that place – for example, from a stroke or head injury – would eradicate the memory completely. As it is, brain trauma and degeneration may nibble away at memories but rarely destroy them entirely. You may lose a person's name, for example, but not the memory of their face.

Accessing Memories
Events that are destined to be recalled are more strongly encoded to begin with than events that are later forgotten. In one study, 16 people viewed 120 photographs and answered which pictures were taken indoors or outdoors. Each image was then shown once again. After 15 minutes, the subjects were shown the photos again, along with some new ones, and asked if they remembered them. Scans taken during the test show strong activation of the hippocampus in response to recalled photos at the first viewing, but less activity in this area when the photos were repeated. This pattern is a "marker" for familiarity.

Inability to Store
In 1953 surgery was performed on a patient known as HM to relieve the symptoms of severe epileptic seizures. The operation involved removing a large part of the hippocampus. This controlled the seizures, but it also produced a severe memory deficit. From the time HM woke up from the operation he was unable to lay down conscious memories. Day-to-day events remained in his mind for only a few seconds or minutes. When he met someone, even a person he had seen many times a day, year after year, he did not recognize them. HM believed himself to be a young man right into his eighties, because the years since his operation did not, effectively, exist for him. His case shows how essential the hippocampus is for memory storage.

LAYING DOWN A MEMORY (158-159)

The Anatomy of Memory
Only experiences giving rise to unusually prolonged and/or intense neural activity become encoded as memories. It takes up to two years to consolidate the changes that create a long-term memory but, once encoded, that memory may remain available for life. Long-term memories include events from a person's life (episodic memories) and impersonal facts (semantic memories). Together, these are termed "declarative memories," since they can be recalled consciously ("declared"). Procedural (body) memories and implicit (unconscious) memories may also be stored long-term.

Hippocampus Replacement
Neuroscientists from the University of Southern California, in Los Angeles, have developed an artificial hippocampus that may one day help people with dementia halt memory loss. The researchers first devised a model of how the hippocampus performs by observing the input-output patterns of the real thing. Then they built the model into a silicon chip designed to interface with the brain, taking the place of damaged tissue. One side of the chip records the electrical activity coming in from the rest of the brain, while the other sends appropriate electrical instructions back out to the brain.

The Location of Memories

After consolidation, long-term memories are stored throughout the brain as groups of neurons that are primed to fire together in the same pattern that created the original experience. “Whole” memories are divided into their components (sensations, emotions, thoughts, and so on); each component is stored in the brain area that initiated it. Groups of neurons in the visual cortex, for instance, will encode a sight, and neurons in the amygdala will store an emotion. The simultaneous firing of all these groups constructs the memory in its entirety.

Forming a Long-Term Memory

0.2 seconds. Attention
The brain can absorb only a finite amount of sensory input at any point. It can sample a little input about several events at once, or focus attention on one event and extract lots of information from that alone. Attention causes the neurons that register the event to fire more frequently. Such activity makes the experience more intense; it also increases the likelihood that the event will be encoded as a memory. This is because the more a neuron fires, the stronger connections it makes with other brain cells.

0.25 seconds. Emotion
Intensely emotional experiences, such as the birth of a child, are more likely to be laid down in memory because emotion increases attention. The emotional information from a stimulus is processed initially along an unconscious pathway that leads to the amygdala; this can produce an emotional response even before the person knows what they are reacting to, as in the “fight or flight” response. Some traumatic events may be permanently stored in the amygdala

0.2 – 0.5 seconds. Sensation
Most memories derive from events that included sights, sounds, and other sensory experiences. The more intense the sensations, the more likely it is that the experience is remembered. The sensational parts of such “episodic” memories may later be forgotten, leaving only a residue of factual knowledge. For example, a person's first experience of seeing the Washington Monument may be reduced to the simple “fact” of what the tower looks like. When it is recalled, it triggers a ghost of a visual image, encoded in the sight area of the brain.

0.5 seconds – 10 minutes. Working memory
Short-term, or “working,” memory is like text on a blackboard that is constantly refreshed. It begins with an experience, and continues as the experience is “held in mind” by repetition. A telephone number, for example, may be repeated for as long as it takes to dial. Working memory is thought to involve two neural circuits around which the information is kept alive for as long as it is needed. One circuit is for visual and spatial information, and the other for sound. The routes of the circuits encompass the sensory cortices, where the experience is registered, and the frontal lobes, where it is consciously noted. The flow of information into and around these circuits is controlled by neurons in the prefrontal cortex.

10 minutes – 2 years. Hippocampal processing
Particularly striking experiences “break out” from working memory and travel to the hippocampus, where they undergo further processing. They cause neural activity that loops around coiled layers of tissue; the hippocampal neurons start to encode this information permanently by a process called long-term potentiation. The strongest information “plays back” to the parts of the brain that first registered it. A sight, for example, returns to the visual cortex, where it is replayed as an echo of the original event.

2 years onward. Consolidation
It takes up to two years for a memory to become firmly consolidated in the brain, and even after that it may be altered or lost. During this time, the neural firing patterns that encode an

experience are played back and forth between the hippocampus and the cortex. This prolonged, repetitive “dialogue” causes the pattern to be shifted from the hippocampus to the cortex; this may happen in order to free up hippocampal processing space for new information. The dialogue takes place largely during sleep. The “quiet” or slow-wave phase of sleep is thought to be more important to this process than rapid eye movement sleep.

RECALL AND RECOGNITION (160-161)

The Nature of Memories

When we recall an event, we reexperience it – but only up to a point. Even when “lost” in reminiscence, we maintain some awareness of the present moment, so the neural activity is not identical to the one that produced the remembered event. Rather, the experience is that of the original mixed with an awareness of the current situation. This experience of remembering “rewrites” the memory, so each time an event is brought to mind it is really a recollection of the last time we remembered it. Hence,memories gradually change over the years, until eventually they might bear very little resemblance to the original event.

State-Dependent Memory

If you learn or experience something when in a certain state of mind or while concurrently experiencing a particular sensation, you will subsequently recall it more readily when you are again in that state. For example, if you read a book on a sunny beach during a vacation, you may seem to forget it completely when you get home. But years later, on another sunny beach, the plot may come flooding back. Similarly, certain behaviors may be learned when in a particular situation or state of mind, and subsequently displayed only when in the same situation or state of mind, and “forgotten” at other times, giving the impression that the person has more than one personality.

Spatial Memory

The structure of the human brain reveals just how important spatial orientation and memory are for our species. The whole parietal lobe of the brain – the area under the crown of the skull – is given over to “maps” of our bodies and of our position in space. Also, a sizeable part of the hippocampus is concerned with registering the landscape through which we travel and laying down memory maps. Damage to either of these areas can seriously affect a person's ability to find his or her way around. If the “navigation” area of the hippocampus is affected by stroke or injury, for instance, a person may lose the ability to remember new routes.

Recognition

Recognizing a person fully involves collating a huge number of memories. They include different types of facts about the person – I know him / he owns a dog / he walked right past me the last time I saw him / his name is Bill. At the same time, you have an emotional reaction to the person based on memories, which produces the feeling of familiarity. Most or all of this happens unconsciously – you see the person and immediately “know” who it is.

Déjà Vu and Jamais Vu

Déjà vu is characterized by a sudden, intense feeling of familiarity and the sense that you have experienced the same moment before. One explanation for this is that the new situation triggers a memory of a similar experience in the past, but the recollection is confused with the present as it is recalled, creating a sense of recognition without bringing to mind the previous event. Research suggests that déjà vu occurs when a new situation is mistakenly “marked” as familiar when processed in the limbic system. Jamais vu, by contrast, occurs when one is in a situation that should be familiar, but which seems strange. You might suddenly find your own home to be unfamiliar, for instance, Jamais vu is thought to be a glitch in recognition, whereby the emotional input that usually accompanies familiar experience fails to occur.

THINKING

INTELLIGENCE (166-167)
"Intelligence" refers to the ability to learn about, learn from, understand, and interact with one's environment. It embraces many different types of skills, such as physical dexterity, verbal fluency, concrete and abstract reasoning, sensory discrimination, emotional sensitivity, numeracy, and also the ability to function well in society.

The Brain's Superhighway
The frontal lobes have long been considered the seat of intelligence since damage to them affects the ability to concentrate, make sound judgments, and so on. Yet frontal-lobe damage does not always affect a person's IQ ("intelligence quotient," measured by testing spatial, verbal, and mathematical dexterity), so other brain areas must also be involved. Recent research suggests that intelligence relies on a neural "superhighway" that links the frontal lobes, which plan and organize, with the parietal lobes, which integrate sensory information. The speed and efficiency with which the frontal lobes receive a stream of ready-to-use data via this route may affect IQ.

Why We Can't Do Two Things at Once
If you try to do something while still working on a previous task, your brain stalls. This may be because the prefrontal cortex, which disengages attention from one task and switches it to another, cannot do so instantly, resulting in a short "processing gap." The brain is also unable to do two similar things simultaneously because the tasks compete for the same neurons. For example, listening to speech while reading words activates overlapping brain areas, so is difficult to achieve, but listening to speech while looking at a landscape is easy.

Factors in Intelligence
Many different factors, relating to both "nature" and "nurture," affect IQ. One is physical development. A brain that has received optimum nutrition during gestation and infancy is primed to work well. Genes influence intelligence, but so do social factors – good nutrition, for example, is clearly less achievable in poverty. Children from poor and/or culturally deprived homes who are moved into a more privileged environment have shown an increase in IQ by up to 16 points. This is thought to be due to increased talking and reading, an interacting in a positive way with family members.

Making Decisions
Intelligence is largely the ability to make sensible decisions, which involves calculating pros and cons. First, the brain assesses the "goal value" - the reward expected as a result of the decision. Next, it calculates the "decision value" - the net outcome, or the reward minus the cost. Finally, the brain makes a prediction of how likely it is that the decision will deliver the reward envisaged, which can be compared with the actual outcome, giving a "prediction error." The more complex the problem, the more the frontal areas of the brain are involved.

What Contributes to Intelligence?	
Tests for IQ measure general intelligence rather than quantity of knowledge or the level of a specific skill. A score of 100 is average, and the vast majority of people fall in the range of 80-120. high scores are correlated with a number of both social and physical factors	
Factor	**Effect**
Genes	There are thought to be about 50 different genes related directly to IQ, but so far very few have been identified. Identical twins raised apart typically have very

	similar IQs, even when raised in strikingly different environments
Brain size	Those with bigger brains compared to other members of the same sex seem to have a slight intelligence advantage. Overall size, however, may be less important than the size, or neural density, of areas concerned with reasoning
Signaling efficiency	The smoothness and speed of neural signaling may determine how much information is available for action and how well it can be integrated into plans. Depression, fatigue, and some types of illness reduce efficiency
Environment	A stimulating social environment in infancy is essential for normal brain development and continues to be important throughout childhood. Verbal interaction seems to be especially useful for IQ

The Numerical Brain
Number sense seems "hard-wired" into the human brain. Babies as young as six months can spot the difference between one and two. One study recorded electrical activity from babies' brains while they watched a pair of soft toys. The toys were then momentarily screened and one was removed, then the screen was lifted to reveal just one toy. The babies' brains registered the "error" by activating the same circuit known to mark error detection in adults, suggesting that even very young babies are able to recognize such discrepancies.

CREATIVITY AND HUMOR (168-169)

The Creative Processing
Our brains are continuously bombarded with stimuli, most of which are ignored. This "shutting out" ensures we use the most relevant information to guide our thoughts. Opening our minds to new information kicks off the creative process. This happens when the brain relaxes out of sharp attentiveness, produced by gamma waves, into "idling," which is characterized by slow, relaxed alpha waves. In this mode, stimuli that might otherwise be ignored enter awareness and resonate with memories, generating new thoughts and ideas that may be both novel and useful.

Creative Individuals
Everyone is creative, but those who can put their brains into "idle" on demand are more likely to open up their minds to new possibilities and generate original ideas. This process only works, however, if the brain is already "primed" with knowledge that can be combined with the new material. Artists who have mastered the basics of their discipline, for instance, have a foundation of knowledge onto which improvements and changes can be fused. Their expertise allows this process to operate unconsciously, leaving greater resources available for processing new stimuli. Creative people also have relatively high IQs, plus the ability to snap back to alertness when a new idea is hatched and to subject the idea to rigorous scrutiny and criticism. Ideas that survive this second creative thought process are likely to be valuable and judged as genuinely new.

Creativity and Madness
Creativity and some types of insanity share certain features, such as intense imagination, a tendency to link things that may seem unconnected to others, and openness to ideas that others may swiftly discount. The difference between highly creative people and those who tip into madness is that creative people maintain insight. They recognize that their imaginings are not real and remain able to control any bizarre symptoms and channel them into their work.

Humor
A lot of humor arises from the juxtaposition of apparently unconnected ideas, which is similar to the process underlying creativity. Studies looking at how humorous interplay between coworkers

affects workplace innovation suggest that keeping workers laughing may "jump-start" their creative faculties, perhaps because humor forces people to attend to "distractions," making them more open to new information. Brain-imaging studies have shown that humor stimulates the brain's "reward" circuit and elevates circulating levels of dopamine, which is linked to motivation and pleasurable anticipation.

Turning on Creativity
As soon as we can categorize a stimulus we tend not to scrutinize it further, but immediately edit it out. So, when we see a dog, we mentally label it as "dog" and do not stop to take in every detail. The frontal lobes manage this editing process, and there is some evidence to suggest that if activity in this area is inhibited, people "take in" more. Tests using transcranial magnetic stimulation (TMS) to "turn off" the frontal lobes show that creative skills can emerge as frontal-lobe activity decreases.

BELIEF AND SUPERSTITION (170-171)

Believing is Seeing
Most people have some kind of belief system, which forms a framework for their experience. Some were taught their beliefs, while others arrived at them by examining their experience and working out their own interpretation. Once a belief system has been formed, it acts both as an explanation for what has happened in the past and also a "working hypothesis" that is projected onto the world. For example, if a person believes that the world is governed by a benign supernatural being, they will "see" events such as coincidences or strokes of good fortune as evidence of this, while a person with a materialist belief system would interpret them merely as chance happenings. People who are quick to see meaningful connections between, for example, random events are more inclined than others to have a magical or superstitious belief system.

Religion in the Brain
Religious practice is largely determined by cultural factors. However, studies of identical twins who have been brought up separately suggest that the likelihood of a person experiencing a religious conversion or spiritual transcendence may be due more to genes than to upbringing. Spiritual transcendence shares some features with other "weird" experiences, such as out-of-body experiences, auras, and "the sensed presence." These are associated with flurries of unusually high activity in the temporal lobes. The areas involved in intense religious experiences seem to be more widespread, however. For example, a study of nuns from a meditative order showed that, as they recalled an intense religious experience, many different areas were activated. So there does not seem to be a single "God-spot."

Brain Chemistry
High natural levels of the neurotransmitter dopamine may explain why some people are unusually quick to pick out patterns. Believers are known to be more likely than skeptics to see a word or face in nonsense images, and skeptics more likely to miss real faces or words that are partly hidden by visual "noise" One study found that skeptics' tendency to see hidden patterns increased when they were given L-dopa, a drug that increases dopamine levels.

The Haunted Brain
Apparently "supernatural" experiences may be due to disturbances in various parts of the brain. Tiny seizures in the temporal lobes are thought to be responsible for many of the emotional effects reported in such events, such as feelings of ecstasy or intense fear. Temporal-lobe disturbance is also associated with the sense of an invisible presence that often accompanies perceiving ghosts. Distortions of space and embodiment, such as the illusion of looking down at oneself, known as an "out-of-body" experience, are linked to reduced activity in the parietal lobes, which normally

maintain a relatively stable sense of space and time. Hallucinations may result from faulty visual or auditory processing or failure to interpret sights and sounds normally.

Making Ghosts

Direct stimulation of the temporal lobes can give a sense of an invisible or divine "presence." Dr. Michael Persinger, of the Laurentian University in Canada, has made a helmet that, he claims, creates "spiritual" experiences in 80 percent of those who try it. Other researchers, however, have failed to reproduce his results and suggest that the effects are due to sensory deprivation and suggestions.

COGNITIVE ILLUSIONS (172-173)

Types of Cognitive Illusion

The brain has certain rules that it applies to incoming information in order to make sense of it quickly. If we hear a voice and at the same time see a mouth moving, for example, we assume the voice comes from the mouth. Like all such rules, though, this is only a best guess and can be wrong. Hence it leaves us open to the illusion of ventriloquy. Low-level illusions those created in the early stages of perception – are unavoidable, but those that arise due to higher-level cognition are less robust. It is impossible no to see the after-image that occurs when you have been looking at a bright light, for example, because this is created by low-level nerve activity, which cannot be affected by conscious thought. However, once you know the voice comes from the ventriloquist rather than the dummy, a result of higher-level cognition, the illusion is less convincing. Illusions may be generated by both conscious and unconscious assumptions. A child's concept of how a horse looks, for example, includes four distinct legs, which governs how the horse is visualized. An "expert" viewer of horses – such as the artist Leonardo Da Vinci – has a more realistic concept.

Distorting Mirrors

Information from the outside world, including sensations from the rest of the body, is constantly compared to a virtual world within the brain, which includes a conceptual map of the body. When the two fail to match up, the brain assumes that something outside has changed. It can even be fooled that the body has shrunk. The shrinking-body illusion involves stimulating the arm muscles with vibrators, to create the feeling that the limbs are moving in, beyond the sides of the body. The brain decides that the body has shrunk.

Ambiguous Illusions

Something strange happens when we look at ambiguous figures. The input to the brain stays the same, but what we see flips from one thing to another. This demonstrates that perception is an active process, driven by information that is already in our brains as well as information from the outside world. The switching occurs because the brain is searching for the most meaningful interpretation of the image. Normally, the brain settles quickly on a solution by using basic rules such as, "if one thing surrounds another, the surrounded shape is the object and the other thing is the ground." Ambiguous figures confound such rules. For instance, in the vase [or two faces facing each other] illusion it is impossible to see which shape is on top, so the brain tries one way of seeing it, then another. You see both images, but you can see never both of them simultaneously.

Distorting Illusions

Distorting illusions are characterized by visual images that generate a false impression of an object's size, length, or curvature. They generally exploit the "allowances" the brain normally makes in order to make sense of what it sees. For example, the brain "allows" that objects of the same size will look smaller if they are farther away, and that larger objects in an array should command greater attention than small ones. Like other illusions, distortions may occur at low or high levels of perception. Those that happen in the earliest stages, before the brain "recognizes" what it is looking at, are the most robust because they cannot be influenced by conscious thought.

Paradox Illusions

It is possible to represent objects in two dimensions that cannot actually exist in the real, three-dimensional world. Paradox illusions are generated by such images, which are often dependent on the brain's erroneous assumption that adjacent edges must join. Although impossible, the best examples are oddly convincing, and the conscious brain is teased and intrigued by them. As with ambiguous illusions, the brain tries first one interpretation and then another, but is unable to settle because none of the available views make sense. Brain-imaging scans show that impossible images are recognized by the brain very early in the process of perception, well before conscious recognition. Unlike the conscious brain, the unconscious part is not very concerned with such images, and spends less time trying to process them than it spends on "real" objects.

CONSCIOUSNESS

WHAT IS CONSCIOUSNESS? (176-177)

Consciousness is like nothing else. A thought, feeling, or idea seems to be different kind of thing from the physical objects that make up the rest of the universe. The contents of our minds cannot be located in space or time. Although they appear to be produced by particular type of physical activity in the brain, it is not known if this activity itself forms consciousness (the Monist/materialist view) or if brain activity correlates with a different thing altogether that we call "the mind" or consciousness (the dualist view). If consciousness is not simply brain activity, this suggests that the material universe is just one aspect of reality and that consciousness is part of a parallel reality in which entirely different rules apply.

Types and Levels of Consciousness

Consciousness has different modes, such as emotions, sensations, thoughts, and perceptions, which are all experienced at different levels of neural activity, focus, and concentration. The level of neural activity determines the intensity of consciousness. The direction of focus can be towards the outside world or the inner world (thinking about thoughts). Concentration can be loosely targeted, involving a range of objects or fixed, involving just one particular aspect. Consciousness also divides into three types of awareness: awareness in the moment – the brain registers and reacts to moment-by-moment events but does not encode them in memory; conscious awareness-events are registered and encoded in memory; and self-consciousness-events are registered and remembered, and the person is conscious of doing this.

LOCATING CONSCIOUSNESS (178-179)

Significant Brain Anatomy

Different types of neuronal activity in the brain are associated with the emergence of conscious awareness. Neuronal activity in the cortex, and particularly in the frontal lobes, is associated with the arousal of conscious experience. It takes up to half a second for a stimulus to become conscious after it has first been registered in the brain. Initially, the neuronal activity triggered by the stimulus occurs in the "lower" areas of the brain, such as the amygdala and thalamus, and then in the "higher" brain, in the parts of the cortex that process sensations. The frontal cortex is activated usually only when an experience becomes conscious, suggesting that the involvement of this part of the brain may be an essential component of consciousness.

Requirements of Consciousness

Every state of conscious awareness has a specific pattern of brain activity associated with it. These are commonly referred to as the neural correlates of consciousness. For example, seeing a patch of yellow produces one pattern of brain activity, seeing grandmother, another. If the brain state changes from one pattern to another, so does the experience of consciousness. The process relevant to consciousness are generally assumed to be found at the level of brain cells rather than at the level of individual molecules or atoms. It is likely that, for consciousness to arise, the factors listed below need to be present. Yet it is also possible that consciousness does arise at the far smaller atomic (quantum) level, and if so it may be subject to very different laws.

SLEEP AND DREAMS (184-185)

The Sleeping Brain
No one is quite sure what is is about sleep that makes it so important. One theory is that it allows "down time" for the body to repair itself. Another is that it simply keeps the person out of danger for a period of time during each day, by keeping him or her still. A third is that the brain needs to switch off from the outside world in order to sort, process, and memorize information. Certainly, important memory functions do occur during sleep, but whether or not this is the primary purpose of sleep remains unclear. Sleep-wake cycles are controlled by neurotransmitters that act on different parts of the brain to induce sleep or waking up. Research also suggests that a chemical called adenosine builds up in the blood while we are awake and causes drowsiness; while we sleep, the chemical is gradually broken down.

Sleepwalking
Sleepwalking happens mainly in the stages of deep sleep and occurs when the blockade that usually prevents motor impulses is lifted, but the other sleep mechanisms remain. Sleepwalkers can do complicated things, such as dressing themselves or even driving cars, but they perform actions robotically, since they are following automatic action plans stored in unconscious parts of the brain.

The Dreaming Brain
There are two types of dreaming. During deep sleep we have vague, often emotionally charged and nonsensical dreams that are often forgotten immediately. The brain is not very active, but seems to be gently processing information in order to lay it down in memory. In REM sleep the brain becomes very active and produces vivid, intense "virtual realities," typically with a narrative. The part of the brain that processes sensations is very active during REM dreaming. The frontal lobes, which include areas that apply critical analysis to our experience, are effectively turned off, so when crazy events happen in our dreams, we just accept them.

Waking and Lucid Dreams
Usually, when shifting from dreaming to waking, several changes occur together in the brain. The block on incoming stimuli is lifted, so external sensory inputs enter the brain again, which overrides and turns off the internally generated sensations that comprise dreams. The block on outgoing signals from the motor cortex is also lifted, so that it becomes possible to move again. Additionally, the frontal lobes are reactivated, shifting us back into a normal state of consciousness in which we know who and where we are, and can tell the difference between fantasy and reality. Lucid dreams occur when the frontal lobes "wake up" during sleep, but the block on incoming and outgoing signals continues. Because the frontal lobes are active, the dreamer is able to deduce that he or she is actually dreaming and experience events in a normal state of mind.

TIME (186-187)

Subjective Time
The passage of time as we experience it (known as subjective time) is not the same as the regular passage of time as measured by our clocks (objective time). The crucial difference is that subjective time can speed up and slow down, according to what we are experiencing. On a moment-by-moment scale, the rate at which time seems to pass is dictated by the rate of firing, or oscillation, of clusters of neurons. The faster they fire, the more events we register in any given second, giving us the impression that time lasts longer. Neuronal firing is controlled by neurotransmitters – excitatory ones speed it up, and inhibitory ones slow it down. Young people

have more excitatory neurotransmitters and, therefore, are able to cope with faster external events.

Catatonia

Catatonia is a state most commonly observed in people with certain types of schizophrenia. The sufferer becomes motionless and stops reacting to external stimuli. They may remain mute, or rigid, for days on end, sometimes striking bizarre poses, which would normally be impossible to maintain. The state seems to come about when the flow of dopamine slows down, and people who have experienced this condition report that they lose all sense of time.

Packets of Time

The brain divides time into "packets" (a cycle of neural activity), each of which registers a single event. The size of the packet depends on how fast the relevant neurons are firing, but regardless of the size of the packet, the brain will only be able to take in one event from that packet. If two events happen, the brain will miss the second one. Some events will always appear blurred to us, such as the beating of a dragonfly's wings, because several flaps occur in each packet.

Backdating Time

It takes on average half a second for the unconscious mind to process incoming sensory stimuli into conscious perceptions. Yet we are not aware of this time lag – you think you see things move as they move, and when you stub your toe you get the impression of knowing about it right away. This illusion of immediacy is created by an ingenious mechanism. Which backdates conscious perceptions to the time when the stimulus first entered the brain. On the face of it, this seems impossible because cortical signals take the same "real" time to process to consciousness, but somehow we are tricked into thinking we feel things earlier. One way it might be explained is that consciousness consists of many parallel streams and that the brain jumps from one to another, revising them and redrafting them.

THE SELF AND CONSCIOUSNESS (188-189)

What is the Self?

We divide the world into that which is subjective and internal and that which is objective and external. The boundary between the two acts like a container, which holds the former and places the latter outside. This container is what we know as the "self." Among other things, it includes our thoughts, intentions, and habits, as well as our actual bodies. Except in altered states, all experiences we report include a sense of self, but most of the time the sense is unconscious. This "consciousness-with-self" is what we generally call "consciousness." When the sense of self becomes conscious, we talk of being "self-conscious."

Agency and Intention

Agency is our sense of control over our actions. We feel that our conscious thoughts dictate what we do, but this appears to be incorrect. A famous experiment by Benjamin Libet revealed that a person's brain starts to plan and execute a movement unconsciously, before the person has consciously decided to do it. This is often interpreted to show that our sense of agency and of making "decisions" is illusory. The sense of agency we experience may actually have evolved primarily to give us early warning not of our own actions, but of the actions of others. Because we feel ourselves to be agents, we also intuit agency in others, and thus think we know their intentions and can predict what they will do.

Schizophrenia and Agency

People with schizophrenia may have a disturbed sense of agency. Some attribute their own actions to the intentions of others, claiming they are being "controlled" by outside forces; others, that they "cause" events unconnected with their own actions, such as moving the sun. studies have suggested that these disturbances of the sense of agency are the result of misperceiving the time gap between action and consequence.

Dislocated Self
The brain holds various “body maps” - internal representations of the physical self. The earliest, most basic map to emerge tells us where our body ends and the rest of the world begins. A more developed body “atlas” enables us to know our spatial location in the world. Normally, the internal maps and the body itself are closely matched, but it is possible for then to be askew. If a person loses a limb, for example, they may develop what is known as a phantom limb – a feeling that they have a limb that, in fact, no longer exists. People can also be tricked into “owning” a limb or even a body that is not actually theirs.

THE INDIVIDUAL BRAIN

NATURE AND NURTURE (192-193)

Genes and the Environment
A gene is a unit of hereditary information linked to one or more physical traits (such as eye color). Genes are made of DNA and some genes achieve their effects by the production of proteins. Genes are like dimmer switches – they can turn their activity (expression) on, off, up, or down. In the brain, gene expression affects the levels of neurotransmitters, which, in turn, influences complex functions like personality, memory, and intelligence. However, neurotransmitters also affect gene expression. Environmental influences affect patterns of gene expression, so that brain function also depends upon factors such as diet, geographical surroundings, social networks, and even stress levels.

The DNA Molecule
Found in the nuclei of all cells in the human body except red blood cells, the DNA molecule is shaped like a twisted ladder – the famous double helix. The two strands of the helix are held together by chemicals called bases, which are arranged in pair. There are four bases, known by the letters A, C, G, and T, and they always pair in the same combinations (A pairs with T, and C pairs with G). the sequence of base pairs can be read by the cell as the instructions for making proteins.

Genetics and the Brain
Proteins have many roles in the body. Some form structures, such as hair, while others, such as enzymes, regulate processes. Several genes in the genome may code for the protein molecules that make serotonin, one of the neurotransmitters involved in mood. Each variant of this gene makes a slightly different protein molecule, which may carry out its job more, or maybe less, efficiently. Thus, gene variants may result in one person having more serotonin, and another person less serotonin. Less serotonin may mean a predisposition to depression or a tendency to overeat. This is also true of other neurotransmitters, such as dopamine – a lack of dopamine has been linked to increased risk-taking behavior. Therefore, your genotype can affect the structure and functioning of your brain, which, in turn, will influence behavior.

Twins
Studies of twins who were separated at birth and brought up in different families have shown that an identical twin reared away from his or her co-twin is still very similar in terms of interests, personality, and attitudes. Therefore, genes would seem to exert a powerful influence on the shaping of the brain throughout life. A classic example is the two “Jims,” who were adopted at the age of four. The adoptive parents – unknown to one another – both named the boys James, and both were known as Jim. Both twins began suffering from tension headaches aged 18. both were

poor spellers but good at math, and as adults, both followed a similar career path in law enforcement.

The Plastic Brain

The brain was once believed to be immutable from birth, with a certain number of brain cells and fixed neuronal circuits. The only changes thought to occur were the loss of brain cells and a reduction in brain volume. But researchers have shown that experience and learning remodel brain circuits. Examples of such neuronal plasticity include long-term potentiation, where memory and learning generate new circuits; the remodeling of the brain after a stroke or in drug addiction to strengthen pathways or create new ones; and the formation of new brain ells (neurogenesis). The brain, it seems, has a certain ability to repair itself and continue to grow and develop throughout life.

INFLUENCING THE BRAIN (194-195)

The Gendered Brain

a number of structural and functional differences have been found between male and female brains. Both the corpus callosum and the anterior commissure (a more primitive connection between the two hemispheres that links the unconscious areas) are larger in women than in men. This may be why women are more emotionally aware – the more emotional right side is better connected to the more analytical left side of the brain. It may also allow emotion to be incorporated more readily into thought and speech. Wen doing complex tasks, women use both sides of their brain, while men use the side more obviously suited to the task.

The Gay Brain

Brain scans show how, in homosexual people, important brain structures involved in mood, emotion, anxiety, and aggression tend to resemble those of heterosexuals of the opposite sex. Heterosexual men tend to have asymmetric brains, with the right hemisphere slightly larger than the left, a characteristic shared by gay women. Patterns of brain connectivity are similar between heterosexual women and gay men, particularly in areas involved with anxiety.

Left or Right Hand?

Around 90 percent of people are right-handed – that is, they use the right hand rather than the left for tasks requiring fine motor control, such as signing their name. Analysis of tools and other archaeological evidence reveals this has been the case since the Stone Age. Right-handedness may be linked to left-hemisphere dominance for language. About 70 percent of left-handed people have language dominance in the left side of the brain, but 30 percent perform language functions using both sides equally. There is also a hypothesis that left-handed people are more likely to be better at visual perception and thinking. About 26 percent of children from two left-handed parents will be left-handed. Only around nine percent of children from two right-handed parents will be left-handed, and there is a high tendency among twins for one to be left-handed.

Cultural Influences

Researchers have shown that culture influences the way the brain works. They carried out tests during fMRI scans on people raised in the US and people raised in East Asia, in which participants did puzzles involving lines in a square. US culture is perceived to be focused upon the individual, while East Asian culture tends to be more focused on family and community. The brains of the US participants had to work harder when they were doing tasks involving context, while those of the East Asians worked harder when they had to judge individual lines. Brain activity lessened when participants undertook tasks related to their culture's comfort zone. Participants were also asked how closely they identified with their culture, and the brains of those who identified most strongly had to work the hardest when doing tasks related to the “opposite” culture.

PERSONALITY (196-197)

Learning to Be You
Each one of us has a genetic blueprint that predisposes us to characteristics such as aggression or extroversion. Although genes contribute greatly to personality development, the way we turn out also depends on how we learn to behave. Personality can be sen as a bundle of habitual responses. These may be learned by copying behavior from caregivers or even from television. If a response is repeated frequently, it is encoded as a memory. Thereafter, it is as much a “part” of the person as a genetic inclination.

Personality and the Brain
Many different personality traits have been linked to specific patterns of activity in the brain, some of which are linked to the expression of certain genes or particular genetic mutations. For example, a person who produces more excitatory neurotransmitters is less likely to feel the need to seek thrills than someone who needs a lot of stimulation to experience the same level of excitement.

Personality Markers in the Brain	
Extroversion	Extroverts have reduced activity, in response to stimuli, in the neural circuit that keeps the brain aroused. As a result, they need more environmental stimuli to keep them feeling energized.
Aggression	People with a version of a gene previously linked to impulsive violence show abnormally reduced volume and usually low activity in the cingulate cortex – an area concerned with monitoring and guiding behavior.
Social Behavior	Socially secure people have a stronger response to friendly looking people in the striatum – an area concerned with reward – than shy people. Avoidant types show a stronger reaction in the amygdala to unfriendly looking people.
Novelty seeking	People who like novelty may have better connections between striatum and hippocampus. The hippocampus sends signals to the striatum – which registers pleasure – when it identifies an experience as new.
Cooperation	Cooperative people show increased activity in the insula if they think their treatment is unfair. Uncooperative people do not register unfairness to the same extent, suggesting an underdeveloped sense of trust.
Optimism	Optimism is linked to enhanced activation in the amygdala and in the anterior cingulate cortex when imaging positive future events relative to negative ones

Personality Assessment
Personality testing is used for many reasons, such as for determining a person's suitability for a job or promotion. Some tests are standardized assessments that require people to answer questions about their typical behavior. The results are used to determine the individual's personality profile. Type tests place people in a particular category. Myers-Briggs, for example, sorts people into categories based on the predominance of certain attributes. Trait tests do not fit people into types, but draw up a profile based on where they lie along a number of dimensions. Projective tests, such as the Rorschach inkblot test, invite people to “reveal” aspects of their personality when responding to ambiguous stimuli.

Many Personalities?
Type tests like the Myers-Briggs have been found to give different results according to the situation in which the person is tested. Trait tests allow for people to be different at different

times, but still assume they have a "major" personality that is more real than others. Some evidence suggests, however, that practically everyone has more than one personality, and that many people have a large number of them. Memories that are available to a person in one situation may not be accessible in another. In extreme cases, this results in dissociative identity disorder (DID), but in normal people it merely shows up as mood changes, memory "glitches," and the coming and going of different skills, behaviors, and ways of seeing the world.

STRANGE BRAINS (198-199)

The Split Brain
The corpus callosum carries signals between the two hemispheres. Rarely, this tissue is surgically severed in people with epilepsy, in order to prevent the spread of seizures. Researchers projected images separately to each hemisphere of split-brain patients. Normally the two sides would share the information via the corpus callosum, but without it each side recognized only its own image. The patients could identify the picture known by the language-dominant left brain, but denied seeing anything else. Yet they were able to select the object seen by the right brain, using the left hand (which is controlled by the right hemisphere). Asked why they selected that object, however, they were unable to say. This suggests that the right hemisphere (in right-handers) is unconscious – even though the information it holds affects behavior.

Weird Brains
Brain scans have revealed some astonishing physical abnormalities, such as brains that are missing an entire hemisphere. The effect of losing half a brain would be catastrophic if it happened in later life. However, several cases have come to light in which brain growth has been severely restricted in infancy and yet the person has gone on to live a near normal life with few, if any, adverse symptoms.

Size Doesn't Matter
Brains do not, generally, vary greatly in size, and there is little evidence to suggest that bigger brains produce greater intelligence. At one extreme, Irish writer Jonathan Swift (1667-1754) had a brain that, at the time of his death, weighted a relatively enormous 70 oz (2,000 g). in 1928, the Moscow Brain Research Institute started collecting and mapping the brains of famous Russians, including that of the physiologist Ivan Pavlov (1949-1936). His brain was at the other end of the size scale, weighing a mere 53 ½ oz (1,517 g).

The Terrorist Brain
Ulrike Meinhof (1934-76) was a ember of the infamous Baader-Meinhof Gang, responsible for a number of killings, bombings, and kidnappings in Germany during the 1970s. She was captured and committed suicide in prison. After her death, studies suggested that brain damage resulting from an operation on a swollen blood vessel might have accounted for her behavior.

Einstein's Brain
Albert Einstein's brain was removed after his death. Many years later, it was examined by Dr. Sandra Witelson and compared with other brains in a brain bank. It was found to be wider than normal, and part of the deep groove that normally runs through the parietal lobe was missing. The area affected is concerned with mathematics and spatial reasoning, and it is possible that the missing groove allowed neurons in that area to communicate more easily, giving him his extraordinary talent for describing the universe mathematically.

DISEASES AND DISORDERS

TENSION HEADACHE

Also known as stress headaches, tension headaches are probably the most common type of headache.
The pain tends to be constant, although it may throb, and it may occur in the forehead or more generally over the head. The pain may be accompanied by tightening of the neck muscles and a feeling of pressure behind the eyes and/or tightness around the head. Tension headaches are typically brought on by stress, which causes tension in the muscles of the neck and scalp. This, in turn, is thought to stimulate pain receptors in these areas, which send "pain impulses" to the sensory cortex.

CLUSTER HEADACHE
These headaches occur in clusters of relatively short attacks of severe, often excruciating, pain.
During cluster headaches there are several attacks (typically one to four) a day, followed by an attack-free remission period. The cluster period usually lasts from a few weeks to a couple of months. A remission period may last for months or even years, although some people experience no significant remissions. The cause of cluster headaches is not known, although there is some evidence that abnormal nerve call activity in the hypothalamus may be involved.

MIGRAINE
A migraine is an intense, often throbbing headache, made worse by movement and often accompanied by sensory disturbances and nausea.
A migraine headache usually occurs at the front or one side of the head, although the area of pain can move during an attack.
Migraine is classified into two types: classical migraine and common migraine. In classical migraine, the headache is preceded by aura, a group of warning symptoms that includes: visual disturbances, such as flashing lights and other distortions; stiffness, tingling, or numbness; difficulty speaking; and poor coordination. In common migraine there is no aura. In both types there may be an early stage, known as prodrome, with features such as difficulty concentrating, mood changes, and fatigue or excessive energy. In common migraine, the prodrome is followed by the headache; in classical migraine, the prodrome is followed by aura, which is then succeeded by the headache. The headache gets worse with movement, and it is accompanied by symptoms including nausea and/or vomiting, and increased sensitivity to sound, light, and sometimes smells. It is often followed by a postdrome stage, in which there may be fatigue, difficulty focusing, poor concentration, and persistence of increased sensitivity.
Causes and triggers
The underlying cause of migraine is not known, but recent research suggests that it may be due to a surge of neuronal activity that sweeps through parts of the brain, eventually stimulating the sensory cortex, which results in the sensation of pain. However, many external factors that trigger migraine attacks have been identified: dietary factors, such as irregular meals, specific foods, and dehydration; physical factors, such as fatigue and hormonal changes; emotional factors, such as stress or shock; and environmental conditions, including changes in the weather or a stuffy atmosphere.

CHRONIC FATIGUE SYNDROME
Also known as myalgic encephalomyeltis (ME), chronic fatigue syndrome is a complex condition that causes extreme fatigue that lasts for a prolonged period of time.
The cause of chronic fatigue syndrome is not known. It can develop after a viral infection or a period of emotional stress, but in many cases there is no specific preceding factor. The principle symptom is persistent, overwhelming fatigue that lasts for at least several months.
Other symptoms vary, but commonly include poor concentration, impaired short-term memory, muscle and joint pain, and feeling ill and/or extremely tired after even mild exertion. The disorder is also often associated with depression or anxiety, but it is unclear whether these are a cause or a result of the condition.

Chronic fatigue syndrome is usually diagnosed from the symptoms, although various tests and psychological assessments can be carried out to exclude other possible conditions. It is a long-term disorder, although there may be periods of remission and sometimes the disorder clears up spontaneously.

HEAD INJURIES

Head injuries range from minor bumps with no long-term effects to brain damage that can be fatal.

Injuries to the head are often classified as closed, in which the skull is not broken, or open, in which the skull is fractured, leaving the brain exposed. Closed head injuries may cause indirect damage to the brain. For example, a hard blow to the head that does not fracture the skull may cause brain injury at the site of impact as the inside of the skull hits the brain. Such a trauma may also cause brain injury at the opposite side of the head (a contrecoup injury). Open head injuries are caused by a strong impact from a sharp object that fractures the skull and may penetrate the brain, for example, a stab wound.

Effects

Head injuries can rupture blood vessels, causing a brain hemorrhage. Minor head injuries typically produce only mild, short-lived symptoms, such as a bruise on the head. In some cases, a temporary disturbance of brain function (concussion) may follow even relatively minor injuries, particularly if the injury has caused unconsciousness, and this may cause confusion, dizziness, and blurred vision, which may last for several days. Postconcussive amnesia can also occur. Repeated concussions eventually cause detectable brain damage, which may result in punchdrunk syndrome, symptoms of which may include impaired cognitive abilities, progressive dementia, parkinsonism, tremors, and epilepsy.

Severe head injury may produce unconsciousness or coma, and usually brain damage, which in very severe cases may be fatal. In nonfatal cases, the effects of brain damage vary widely according to the severity and location of damage. The effects may include weakness, paralysis, problems with memory and/or concentration, intellectual impairment, and even personality changes. Such effects can be long-term or permanent.

EPILEPSY

Epilepsy is a brain function disorder in which there are recurrent seizures or periods of altered consciousness.

Normally, neuronal activity in the brain occurs in a regulated way. However, during an epileptic seizure neurons start firing in an abnormal way, disrupting normal brain function. Although seizures are a defining symptom of epilepsy, they can occur without epilepsy being the cause.

The mechanism underlying epileptic seizure is not known for certain, but it is thought to involve a chemical imbalance in the brain. Normally, the neurotransmitter gamma-aminobutyric acid (GABA) helps regulate brain activity by inhibiting neurons in the brain. When the level of GABA falls too low – which itself may be due to abnormal amounts of enzymes that regulate GABA levels – neurons are not inhibited and they send a flood of impulses through the brain, resulting in a seizure. Epilepsy can have a number of causes, although in many cases the cause is unclear. A genetic factor may be involved in some cases. Other causes include head injury; birth trauma; an infection such as meningitis or encephalitis; a stroke; a brain tumor; and abuse or drugs or alcohol.

Many people find that specific factors can trigger a seizure. These triggers include stress; lack of sleep; fever; flashing lights; and drugs such as cocaine, amphetamines, Ecstasy, and opiates. Some women who suffer from epilepsy are more likely to have a seizure before the start of a menstrual period.

MENINGITIS

Meningitis is inflammation of the meninges, the membranes covering the brain and spinal cord, often as a result of a viral or bacterial infection.

Typically, the infection reaches the meninges through the bloodstream from elsewhere in the body, although it may occasionally result from direct infection of the meninges after an open head injury. It may occur as a complication of various other diseases, including Lyme disease, encephalitis, tuberculosis, and leptospirosis. Viral meningitis may be caused by viruses such as herpes simplex or chickenpox virus. It tends to be relatively mild and causes symptoms similar to those of flu. Rarely, it may cause serious symptoms, such as weakness or paralysis, speech problems, visual impairment, seizures, and coma.

Bacterial meningitis is less common than the viral form, but is more serious and can be fatal. It may be caused by various bacteria but is usually due to infection with meningococcal or pneumococcal bacteria. Symptoms may develop rapidly, over only a few hours, and include fever, stiff neck, severe headache, nausea, vomiting, abnormal sensitivity to light, confusion, and drowsiness, and sometimes seizures and loss of consciousness. In meningococcal meningitis, the bacteria may multiply in the blood, leading to a reddish purple rash that does not fade when pressed. If left untreated, bacterial meningitis can enter the cerebrospinal fluid, triggering an immune response that causes increased intracranial pressure, which in turn can cause brain damage.

ENCEPHALITIS

Encephalitis is inflammation of the brain. It is usually due to infection by a virus or may occur as a result of an autoimmune reaction.

A rare condition, encephalitis varies in severity from a mild, barely noticeable illness to one that can be life-threatening.

Only certain viruses are able to gain access to the central nervous system and affect nerves, and therefore potentially cause encephalitis. These viruses include the herpes simplex virus (which also causes cold sores), chickenpox virus, and measles virus. Occasionally, the infection may also affect the meninges, causing meningitis. In most cases, the immune system deals with the viral infection before it can affect the brain. However, if the immune system is compromised, there is a greater risk of developing encephalitis. When encephalitis develops, the infection causes swelling, and parts of the brain may be damaged when it is compressed against the skull. Rarely, encephalitis is due to an autoimmune reaction, in which the immune system attacks the brain, leading to inflammation and brain damage.

Mild encephalitis usually causes only a slight fever and headache. In more severe cases, there may also be nausea and vomiting; weakness, loss of coordination, or paralysis; abnormal sensitivity to light; loss or impairment of speech; memory loss; uncharacteristic behavior; stiff neck and back; drowsiness; confusion; seizures; and coma. In very severe cases, encephalitis can cause permanent brain damage and may even be fatal.

BRAIN ABSCESS

An abscess is a collection of pus, surrounded by inflamed tissue, that can form in the brain or on its surfaces. There may be several at once.

A brain abscess can result from a bacterial or, more rarely, a fungal or parasitic infection. Fungal and parasitic infections are usually restricted to people whose immune systems have been impaired – for example, those with HIV/AIDS, people undergoing chemotherapy, or those taking immunosuppressants.

A brain abscess can occur as a result of a penetrating head injury or an infection spreading from elsewhere in the body, such as from a dental abscess, middle-ear infection, sinusitis, or pneumonia. It can also result from injecting drugs using a nonsterile needle.

Symptoms and effects

Once an abscess has formed, the tissue around it becomes inflamed, which may cause brain swelling and increased pressure in the skull, symptoms may develop over a few days or weeks and depend on the area of the brain affected. Common general symptoms include: headache; fever; nausea and vomiting; stiff neck; drowsiness; confusion; and seizures. A person may also experience speech difficulties, vision problems, and weakness of the limbs.

A brain abscess can be diagnosed by a scan and tests to identify the infecting organisms. Without treatment, an abscess can cause unconsciousness, and a coma may develop. It may also lead to permanent damage, and in some cases can be fatal. Drug treatment can eliminate the infection and reduce the swelling in the brain, but a craniotomy (a procedure to make a small opening in the skull) may be needed to drain pus from a large abscess.

TRANSIENT ISCHEMIC ATTACK

This is an episode of temporary loss of brain function due to an interruption of the blood supply to part of the brain.

Also called a "mini-stroke," a transient ischemic attack (TIA) is most commonly caused by a blood clot that temporarily blocks an artery supplying blood to the brain. It can also occur due to excessive narrowing of an artery as a result of atherosclerosis (buildup of fatty deposits on the artery wall). There are numerous risk factors that contribute to the likelihood of a TIA, such as diabetes mellitus, previous heart attacks, high blood-fat levels, high blood pressure, and smoking.

Symptoms usually develop suddenly and vary according to the part of the brain affected by the restricted blood flow, but they include visual disturbances or loss of vision in one eye, problems speaking or understanding speech, confusion, numbness, weakness or paralysis on one side of the body, loss of coordination, dizziness, and possibly brief unconsciousness. If symptoms last for more than 24 hours, the attack is classed as a stroke. Having had a TIA indicates increased risk of stroke.

Treatment for TIA is aimed at preventing a stroke and includes endarterectomy (a procedure to remove the lining of an artery affected by atherosclerosis), anticoagulant drugs, or aspirin. It is also important to treat any risk factors, and stopping smoking is essential.

STROKE

Damage to parts of the brain can occur when blood supply to the brain is interrupted.

Interruption to the blood supply to the brain can occur as a result of a blockage of an artery in the brain (ischemic stroke), bleeding into the brain from a ruptured artery (hemorrhagic stroke), bleeding from a blood vessel in the brain (possibly from a ruptured aneurysm), or a subarchnoid hemorrhage. Risk factors include age, high blood pressure, atherosclerosis, smoking, diabetes mellitus, heart-valve damage, previous or recent heart attack, high blood-fat levels, certain heart-rhythm disorders, and sickle cell disease.

Symptoms and effects

Symptoms develop suddenly and vary depending on the brain areas affected, but can include sudden headache, numbness, weakness or paralysis, visual disturbances, problems speaking or understanding speech, confusion, loss or coordination, and dizziness. If severe, a stroke can cause loss of consciousness, coma, and death.

Treatment depends on the cause – strokes due to a clot require drugs and hemorrhagic strokes may require surgery. Nonfatal strokes can cause long-term disability or impairment of function, for which rehabilitative therapies (such as physical therapy and speech therapy) may be required.

SUBDURAL HEMORRHAGE

A ruptured blood vessel can cause bleeding between the two outer meninges that surround the brain.

The most common cause of a subdural hemorrhage is a head injury – it can occur from minor injuries, especially in the elderly.

After the injury, bleeding may occur rapidly (within minutes) in the case of an acute subdural hemorrhage, or slowly over days or weeks for a chronic subdural hemorrhage. The trapped blood forms a clot in the skull that compresses brain tissue and causes symptoms. These are variable and may fluctuate depending on the area of the brain affected. They may include headache, one-sided paralysis, confusion, drowsiness, and seizures. In several cases, there may be unconsciousness and coma. The long-term outcome depends on the size and location of the hemorrhage. A severe subdural hemorrhage may be fatal.

A subdural hemorrhage is usually diagnosed with a brain scan (CT or MRI). An X-ray may be taken if skull fracture is suspected. A small hemorrhage may not need treatment and can clear up on its own, but usually surgery is needed.

SUBARACHNOID HEMORHAGE

A subarachnoid hemorrhage is caused by bleeding into the space between the two outer embranes surrounding the brain.

This type of hemorrhage is most commonly caused by rupture of a berry aneurysm or, rarely, is due to the rupture of an arteriovenous malformation. High blood pressure is a significant risk factor. Symptoms occur suddenly, without warning, and often develop rapidly (over minutes). Some people recover completely, some are left with residual disability, and some die. Arteries in the brain may constrict to reduce blood loss, which can reduce blood supply to part of the brain and cause a stroke.

BRAIN TUMORS

benign or malignant growths can form in the brain or in the membranes around the brain and spinal cord.

Primary brain tumors first develop in the brain itself and can be malignant or benign. They can arise in various types of brain cells and in any part of the brain, but primary tumors in adults are most common in the front two-thirds of the cerebral hemispheres.

Secondary tumors result from the spread of malignant cancer (metastasis) from elsewhere in the body, most commonly the lungs, skin, kidney, breast, or colon. Several secondary tumors can develop simultaneously and the cause of most tumors is not known. Rarely, some tumors may be associated with certain genetic conditions.

A tumor compresses the surrounding brain tissue and raises pressure inside the skull. Symptoms therefore depend on the seize and location of the tumor, but may include severe, persistent headaches; blurred vision or other sensory disturbances, speech problems; dizziness; muscle weakness; poor coordination; impaired mental functioning; behavioral or personality changes; and seizures. If left untreated, a brain tumor may be fatal.

Brain tumors are diagnosed through brain scans and neurological tests. Treatment may involve a surgical removal (if possible), radiation therapy, and/or chemotherapy. Drugs to reduce the brain swelling may also sometimes be given.

DEMENTIA

This disorder is characterized by a generalized decline in brain function, producing memory problems, confusion, and behavioral changes.

Dementia is caused by microscopic damage to brain tissue that leads to atrophy. It can be caused by various disorders […]. most commonly, it is due to Alzheimer's disease. Another common cause is vascular dementia, in which reduced or blocked blood supply causes death of brain cells. This can occur suddenly due to a stroke or gradually through a series of small strokes. Other causes include frontotemporal degeneration; Lewy body dementia, in which small, round structures appear in brain cells, leading to the degeneration of affected brain tissue; and neurological deterioration associated with conditions such as AIDS, Wernicke-Korsakof syndrome, Creutzfeldt-Jakob disease, Parkinson's disease, Huntington's disease, head injury, brain tumors, and encephalitis. In rare cases, it may occur due to vitamin or hormone deficiency, or as a side effect of certain medications. Rarely, dementia may be caused by inherited genetic mutations.

Symptoms and effects

Dementia is characterized by progressive memory loss, confusion, and disorientation. It can also give rise to atypical or embarrassing behavior, personality changes, paranoia, depression, delusions, unusual irritability, and anxiety. The affected person may make up explanations to account for memory gaps or strange behavior. As the condition progresses, a person with dementia may become indifferent towards other people and external events, as well as his or her own personal hygiene.

In rare cases, dementia may be due to a treatable cause, such as side effect of medication or a vitamin deficiency, but usually there is no cure. Most forms are progressive, and a person may need total nursing care. Treatment with drugs may slow the deterioration of mental function and improve behavioral symptoms.

ALZHEIMER'S DISEASE

The most common cause of dementia, this is a progressive degenerative condition in which plaques cause damage to the brain.

Alzheimer's disease is rare before the age of 60, but increasingly common thereafter. Most cases occur without an identifiable cause. Mutations in several genes are associated with this disorder, however, and the genetic component is especially strong in the relatively rare cases of early onset disease (symptoms occurring before 60). in late-onset Alzheimer's disease, mutations in genes responsible for the production of a blood protein called apoliprotein E are implicated. These genes result in a protein (beta amyloid) being deposited in the brain as plaques, which leads to the death of neurons. Alzheimer's disease is also associated with reduced levels in the brain of the neurotransmitter acetylcholine. Additionally, it is thought that the disruption of the mechanism that controls the inflow of calcium ions into neurons may be involved, leading to excessive calcium in the neurons, which prevents them from receiving impulses from other brain neurons.

Symptoms may vary from one person to another, but typically Alzheimer's progresses through three stages. Alzheimer's disease is usually diagnosed from the symptoms, although brain scans, blood tests, and neuropsychological tests are also carried.

Treatment

Treatment for this disorder is aimed at slowing down the degeneration, but it does not completely halt decline, and eventually complete nursing care is needed. Acetylcholinesterase *inhibitors* may slow progress of Alzheimer's disease in the early and middle stages, and memantine in the later stages.

CREUTZFELDT-JAKOB DISEASE

Dementia can be caused by an abnormal prion protein that accumulates in the brain, causing widespread destruction of brain tissue.

Prions are proteins that occur naturally in the brain, but their function is unknown. These proteins may become abnormally distorted, forming clusters in the brain and destroying brain tissue. This tissue destruction leaves holes in the brain, giving it a spongelike appearance, and results in various neurological dysfunctions, dementia, and finally death. There are four main types of Creutzfeldt-Jacob disease: sporadic CJD; familiar CJD; iatrogenic CJD; and variant CJD, which is caused by infection with bovine spongiform encephalopathy (BSE).

Initial symptoms include memory lapses, mood changes, and apathy. These may be followed by clumsiness, confusion, unsteadiness, and speech problems. Toward the final stages there may be uncontrollable muscle spasms, stiffness of the limbs, impaired vision, incontinence, progressive dementia, seizures, and paralysis. Eventually, CJD is fatal.

PARKINSON'S DISEASE

This is a progressive brain disorder that causes tremors, muscle rigidity, problems with movement, and difficulty keeping balance.

Parkinson's disease is caused by degeneration of cells in the substantia nigra nuclei of the midbrain. These cells produce dopamine, a neurotransmitter that helps control muscles and movement. Damage to the cells reduces dopamine production, leading to the characteristic motor symptoms of Parkinson's disease.

In most cases, the underlying cause is not known, although in a very few cases, specific genetic mutations have been linked to Parkinson's disease. Symptoms usually develop gradually (over months or years), typically beginning with a tremor in a hand, arm, or leg that is worse when at rest. As the disease progresses, it becomes difficult to initiate voluntary movements; walking becomes a shuffling motion – it may be difficult to take the first step, and the normal arm swing

when walking may be reduced or lost; muscles become rigid; handwriting becomes small and illegible; posture becomes stooped; and there may loss of facial expression.
In the late stages, there may be problems speaking, swallowing may be difficult, and depression may occur. The intellect is usually unaffected, although dopamine depletion may cause symptoms of dementia.

HUNTINGTON'S DISEASE

Huntington's is a rare, inherited disease in which neurons in the brain degenerate, leading to jerky, uncontrolled movements and dementia.

The underlying cause of Huntington's disease is a single abnormal gene that occurs when a group of DNA base pairs is repeated many times. The faulty gene generates an abnormal version of Huntington protein, which then builds up in never cells and leads to the degeneration of neurons in the basal ganglia and cerebral cortex.

Effects

Symptoms usually start to appear between the ages of 35 and 50, although they may sometimes start in childhood. Early symptoms include chorea (jerky, rapid uncontrollable movements), clumsiness, and involuntary facial grimaces and twitches. Other symptoms then develop, including speech problems; difficulty swallowing; depression; apathy; and dementia, which usually takes the form of lack of concentration, memory problems, and personality and mood changes (including aggressive or antisocial behavior). The disease usually progresses slowly, eventually causing death some 10-30 years after symptoms first appear. A diagnosis of Huntington's disease is made from the symptoms, with brain scans, and also genetic (to test for the abnormal gene) and neuropsychological testing.
There is no cure for Huntington's disease, and drug treatment is aimed at reducing the symptoms. Keeping physically and mentally active is also advised.

MULSIPLE SCLEROSIS

A progressive disease, multiple sclerosis causes the destruction of the myelin sheaths that surround neurons in the brain and spinal cord.

Multiple sclerosis (MS) is thought to be an autoimmune disease in which the body's immune system destroys the cells that produce the myelin sheaths that surround and insulate neurons. Eventually hardened (sclerosed) plaques of scar tissue form over the demyelinated areas and the neurons themselves degenerate. The effect of these changes is to impair or block nerve impulses. The reason for this autoimmune reaction is not known, although there may be genetic, environmental, or infectious factors involved.
The course and symptoms of MS vary among individuals. In addition to common symptoms, there may also be mental changes, such a spoor memory, anxiety, and depression. The most common type is relapsing – remitting MS, in which attacks (relapses) of gradually worsening symptoms are followed by periods of remission. In progressive MS, symptoms worsen without remission. In most cases, relapsing – remitting MS may develop into progressive MS.

MOTOR NEURON DISEASE

In this group of disorders, progressive degeneration of motor neurons leads to increasing weakness and wasting of muscles.

In most cases, the cause of motor neuron disease (MND) is not known. However, genetic factors are thought to be important in affecting a person's susceptibility to the condition. Some rare types of MND are inherited. Motor neuron disease can affect the upper motor neurons (those originating in the motor cortex or brainstem) and/or the lower motor neurons (those in the spinal cord and brainstem that connect the central nervous system to the muscles). Damage to the upper motor neurons is indicated by spasticity, muscle weakness, and exaggerated reflexes. Damage to the lower motor neurons produces a weakening of muscles, paralysis, and atrophy of the skeletal muscles.

In addition to muscular symptoms, some people also experience personality changes and depression, but intellect, vision, and hearing remain unaffected.
There are many types of motor neuron disease, the most common of which are amyotrophic lateral sclerosis (ALS, or Lou Gehrig's disease) and progressive bulbar atrophy. Both these types affect both the upper and lower motor neurons.

PARALYSIS

Partial or complete loss of controlled movement due to impaired muscle function may be the result of a nerve or muscle disorder.

Paralysis can affect areas ranging from a single small muscle to most of the major muscles of the body. It is classified by the areas of body affected. Hemiplegia is paralysis of one half of the body. Paraplegia is the paralysis of both legs and sometimes part of the trunk. Quadriplegia is paralysis of all four limbs and the trunk. Paralysis may also be classified as “flaccid” (causing floppiness) or “spastic” (causing rigidity).
Paralysis can be caused by any injury or disorder that affects the motor cortex or the motor nerve pathways that run from the motor cortex via the spinal cord and peripheral nerves to the muscles. It may also result from a muscle disorder or myasthenia gravis (a disorder affecting the junction between nerves and muscles). The affected area sometimes feels numb.

DOWN SYNDROME

Also known as trisomy 21, down syndrome is a chromosomal abnormality that affects both mental and physical development.

One of the most common chromosomal abnormalities, Down syndrome is usually the result of an extra copy of chromosome 21; affected people therefore have 47 chromosomes in all of their body cells, rather than 46. it may also result when part of chromosome 21 breaks off and attaches to another chromosome, a process called translocation, so that cells have the normal number of chromosomes but chromosome 21 is abnormally sized. Very rarely, Down syndrome may be the result of mosaicism, in which some body cells have 47 chromosomes and some have 4. exactly how these abnormalities produce the characteristic mental and physical features of Down is not known.
In most cases there is no identifiable reason for the chromosomal abnormality, although maternal age is a risk factor – after the early 30s, the risk of having a child with Down increases significantly. Paternal age can also be a risk factor, if the father is over 50. parents who already have a child with Down or who have abnormalities of their own chromosome 21 have a higher risk of having a baby with Down syndrome.

Symptoms

There is considerable variation in the severity of symptoms, but typically they include slow motor and language development and learning difficulties. Physical symptoms may include a small face with upward-sloping eyes; a flattened back of the head; a short neck; a large tongue; small hands with a single horizontal crease on the palm; and short stature. There is also increased risk of various disorders, such as heart disease (often associated with congenital heart problems), hearing problems, underactivity of the thyroid gland, narrowing of the intestines, leukemia, and respiratory-tract and ear infections. Adults are at increased risk of eye problems such as cataracts. In older people there is a heightened risk of Alzheimer's disease. People with Down syndrome have lower than normal life expectancy, but some survive into old age.

CEREBRAL PALSY

Cerebral palsy refers to a group of disorders that affect movement and posture due to brain damage or the failure of the brain to develop properly.

There are many possible causes of cerebral palsy, and often the cause is not identified. Usually, the brain damage occurs before or around birth. Possible causes include extreme prematurity; lack of oxygen to the fetus before or during birth (hypoxia); hydrocephalus; infection transmitted from the mother to the fetus; or hemolytic disease, which is caused by a blood incompatibility between

the mother and the fetus. After birth, infections such as encephalitis and meningitis, head injury, or a brain hemorrhage may cause cerebral palsy.
In additional to movement and posture abnormalities and difficulties that these can cause (such as difficulty walking, talking, and eating), cerebral palsy may also give rise to various other problems, such as vision and hearing impairment and epilepsy. It may also sometimes cause learning difficulties. The severity of symptoms varies widely among different people, from slight clumsiness to severe disability.
There is no cure for cerebral palsy, but treatment includes physical therapy, occupational therapy, and speech therapy. Drugs may be used to control muscle spasms and increase joint mobility. Surgery may help correct any deformities that have developed as a result of abnormal muscle development. Cerebral palsy is not progressive.

HYDROCEPHALUS

Commonly known as water on the brain, hydrocephalus is an excessive buildup of cerebrospinal fluid within the skull.

Hydrocephalus occurs either because excess cerebrospinal fluid is produced or because the fluid does not drain away normally. The fluid accumulates in the skull and compresses the brain, which ay lead to brain damage.
This condition can be present at birth, often in association with other abnormalities, such as a neural-tube deficit. The main symptom is an abnormally large head that continues to grow rapidly without treatment, severe brain damage may occur, which may lead to cerebral palsy or other physical or mental disabilities, or may even be fatal.
Hydrocephalus may occur later in life, as a result of a head injury, brain hemorrhage, infection, or a brain tumor. It usually clears up once the cause is treated.

NEURAL-TUBE DEFECTS

A number of developmental abnormalities of the brain or spinal cord can occur when the neural tube does not form properly.

The neural tube is the region along the back of an embryo that develops into the brain, spinal cord, and meninges. The cause of neural-tube defects is unknown, but they tend to run in families and have been associated with certain anticonvulsant drugs during pregnancy. A lack of folic acid during early pregnancy is also associated with the defects.
The most common types are anencephaly and spina bifida. In anenecephaly there is a complete lack of a brain, which is always fatal. In spina bifida the vertebrae do not close completely around the spinal cord. In the most severe form of spina bifida, called myelomeningocele, the spinal cord is malformed and there may be paralysis of the legs and loss of bladder control.

NARCOLEPSY

This is a neurological disorder characterized by chronic drowsiness and recurrent, sudden episodes of sleep throughout the day time.

This condition is thought to be due to abnormally low levels of proteins called hypocretins (also known as orexins) in the brain. Hypocretins are produced by cells in the hypothalamus and help regulate sleep and wakefulness. In people with narcolepsy, these cells are damaged. The underlying cause of the damage is not known, but it may be due to an autoimmune response, possibly triggered by an infection. A genetic factor may be involved, as the condition tends to run in families.
The main symptoms are overwhelming drowsiness and an uncontrollable urge to sleep – people with narcolepsy may fall asleep without warning at any time and place. Other common symptoms include a sudden loss of muscle tone (cataplexy) while awake and hallucinations at the start or end of sleep.

COMA

A state of unconsciousness in which there is a lack of responsiveness to internal and external stimuli is called a coma.

Coma results from damage or disturbance to parts of the brain involved in maintaining consciousness or conscious activity, especially the limbic system and the brainstem. A wide range of problems can cause a coma, including head injury; lack of blood supply to the brain, as may occur after a heart attack or stroke; infections, such as encephalitis and meningitis; toxins, such as carbon monoxide or drug overdoses; and prolonged high or low blood-sugar levels, as can occur in diabetes mellitus.

Symptoms

There are varying degrees of coma. In less severe forms, the person may respond to certain stimuli and spontaneously make small movements. In the condition known as a persistent vegetative state there may be sleep-wake cycles, movements of the eyes and limbs, and even speech although the person does not appear to respond to any stimuli. In a deep coma, the person does not respond to any stimuli nor make any movements, although automatic responses such as blinking and breathing may be maintained. In severe cases, in which the lower brainstem is damaged, vital functions such as breathing are impaired or lost and life support is necessary. Total and irreversible loss of brainstem function is classed as brain death.

DEPRESSION

Depression is characterized by persistent feelings of intense sadness, hopelessness, and loss of interest in life that interfere with everyday life.

In many cases, depression occurs without an obvious cause. A number of factors may trigger it, such as a physical illness; hormonal disorders or the hormonal changes during pregnancy (prenatal depression) or after childbirth (postpartum depression); or distressing life events, such as a bereavement. It may also occur as a side effect of certain drugs, such as oral contraceptives. Depression is more common in women, it tends to run in families, and various genetic mutations are associated with this disorder.

Various biological abnormalities have been found in the brains of depressed people, such as decreased levels of the neurotransmitter serotonin, raised levels of the enzyme monoamine oxidase,loss of cells from the hippocampus (an area of the brain involved in mood and memory), and abnormal patterns of neural activity in the amygdala and parts of the prefrontal cortex. However, the mechanisms by which such biological abnormalities may lead to depression are not known.

Symptoms and treatment

There is considerable variation among different people in the symptoms and in their severity. Most people experience several of the following; feeling unhappy most of the time; loss of interest and enjoyment in life; difficulty coping and making decisions; impaired concentration; persistent fatigue; agitation; changes in appetite and weight; disrupted sleeping patterns; loss of interest in sex; loss of self-confidence; irritability; and thoughts of, or attempts at, suicide. In some people, episodes of depression alternate with periods of extreme highs (manic episodes); this is known as bipolar disorder.

Usually depression is treated with a talking therapy, antidepressant drugs, or both. Experimental treatment using deep brain stimulation (where implanted electrodes stimulate areas of the brain) is also being studies.

BIPOLAR DISORDER

Bipolar disorder is a mood disorder characterized by mood swings between depression and mania.

The exact cause of bipolar disorder (sometimes called manic-depressive illness) is not known, although it is believed that it results from a combination of biochemical, genetic, and environmental factors. The levels of certain neurotransmitters in the brain, such as norepinephrine, serotonin, and dopamine, may play a role. Bipolar disorder tends to run in families and has a strong genetic component. However, environmental factors, such as a major life event, may act as triggers.

Symptoms
Typically, symptoms of depression and mania alternate, with each episode lasting for an unpredictable period. Between mood swings, a person's mood and behavior are often normal. Symptoms of a depressive episode may include feelings of hopelessness, disturbed sleep, changes in appetite and weight, fatigue, a loss of interest in life, and a loss of self-confidence; there may also be suicide attempts. Symptoms of a manic episode may include extreme optimism, increased energy levels, drive and activity, inflated self-esteem, racing thoughts, and risk-taking behavior.
Creativity and Bipolar Disorder
Biographical studies suggest that bipolar disorder may be more common among accomplished artists than in the general population, and some artists seem to be able to utilize periods of mania as a spur to creativity. For example, the musical output of the German composer Robert Schumann (1810-56) […] shows a link between his bouts of mania and the number of compositions he produced. He was most productive during manic phases and least productive when depressed. However, the quality of his work was not affected by his moods.

ANXIETY DISORDERS
This is a group of disorders in which feelings of anxiety and/or panic occur frequently enough to cause problems in coping with everyday life.
Temporary feelings of nervousness, apprehension, and even panic in stressful situations are normal and appropriate. However, when these anxiety reactions occur frequently in ordinary situations and disrupt normal activities, it is considered to be a disorder. In a few cases there may be an identifiable physical cause for persistent anxiety, such as a thyroid disorder or substance abuse, and sometimes generalized anxiety may develop after a stressful life event, such as a bereavement. In most cases the cause is not known, although a family history of an anxiety disorder increases the risk of developing one. The brain mechanisms underlying anxiety disorders are also unknown, although disruption of neurotransmitters in the frontal lobes or limbic system may be involved.
Whatever the underlying cause, the effect is to disrupt the body's normal control of its stress response – the "fight or flight" response. With anxiety disorders either the stress response fails to turn off or the stress response becomes activated at inappropriate times.
There are several forms of anxiety disorder. The most common is generalized anxiety disorder, which is characterized by excessive, inappropriate worrying that lasts for at least six months. Another form of anxiety disorder is panic disorder, in which there are sudden, unexpected attacks of intense anxiety or fear.

PHOBIAS
A phobia is considered to be a disorder when persistent, irrational fears of particular things, activities, or situations disrupt everyday life.
There are many different forms of phobia, but they can be categorized into two broad types: simple and complex. Simple phobias are fears of specific objects or situations, for example, spiders (arachnophobia) or enclosed spaces (claustrophobia). Complex phobias are more pervasive and involve several anxieties. For example, agoraphobia may involve fear of crowds and public places or of traveling in planes, buses, or other forms of public transportation; it also includes anxiety about being unable to escape to a safe place, usually home. Social phobia (also known as social anxiety disorder) is another complex phobia in which there is intense anxiety in social or performance situations (such as public speaking) because of fear of public embarrassment or humiliation.
Causes and effects
The causes of phobias are not known for certain. Some phobias tend to run in families, which may be a result of children learning a specific fear from their parents. In other cases, a phobia may develop in response to a traumatic event or situation.
The main symptom of a phobia is an intense, uncontrollable anxiety when confronted by the feared object or situation. Merely anticipating an encounter with the feared object or situation can cause

anxiety. In several cases there may be symptoms of a panic attack, such as sweating, palpitations, breathing difficulty, and trembling, when the object or situation is actually encountered. There is also usually a strong desire to avoid the feared object or situation, often to the extent of taking extreme measures. These effects can severely limit normal everyday activities and sometimes a person with a phobia may try using drugs or alcohol in an attempt to reduce the anxiety.

POST-TRAUMATIC STRESS DISORDER

A severe anxiety response can develop after a person is involved in or witnessed a distressing or life-threatening event, such as a terrorist atrocity, a natural disaster, rape or physical violence, serious physical injury, or military combat.

The external cause of post-traumatic stress disorder (PTSD) is the experience of trauma. In the brain itself, various abnormalities in areas involved in memory, the stress response, and the processing of emotions have been identified. The amygdala (involved in memory and emotion processing) is overactivated in response to memories of traumatic events whereas the prefrontal cortex is under-responsive to fearful stimuli, which may result in its failure to inhibit the amygdala and thereby inhibit traumatic memories. The thalamus may also be involved; some people have a genetic constitution that is associated with an enlarged thalamus, which may in turn lead to an exaggerated response to fearful memories and an increased susceptibility to PTSD.

Symptoms and treatment

The symptoms of PTSD may develop immediately after a traumatic event or may not appear for months. They may include flashbacks or nightmares that trigger the same intense fear originally felt; emotional numbness; loss of enjoyment in usually pleasurable activities; memory problems; hypervigilance and an exaggerated startle response; sleeping problems; and irritability.

OBSESSIVE-COMPULSIVE DISORDER

Commonly known as OCD, obsessive-compulsive disorder is characterized by recurrent thoughts that cause anxiety and/or overwhelming urges to perform repetitive acts or rituals in an attempt to relieve anxiety.

The exact cause of OCD is not known, but it is generally thought to be due to a combination of factors and may have different causes in different people. OCD tends to run in families, so there may be a genetic link in some cases. It has also been associated with childhood infection with Streptococcus bacteria. Brain imaging studies have found evidence of abnormal physiological connections in the communication loop between the orbitofrontal cortex, caudate nucleus, and thalamus involving the neurotransmitter serotonin. In addition, personality type may be a factor – perfectionists appear to be more susceptible to developing OCD.

Symptoms

Symptoms typically appear during the teenage or early adult years and may consist of obsessions, compulsions, or both. Obsessions are thoughts, feelings, or images that recur involuntary and provoke anxiety. For example, there may be an excessive fear of dirt that may be so powerful that the person fears leaving home in case he or she becomes contaminated. Compulsions are actions that a person feels compelled to carry out repeatedly in an effort to ward off anxiety, such as repeatedly checking things such as locks or doors. The person may recognize that the obsessions and/or compulsions are unreasonable but cannot control them.

Diagnosis and outlook

To be diagnosed with OCD, the symptoms must cause anxiety, must be present on most days for at least two weeks, and must interfere significantly with everyday life. With treatment most people recover, although symptoms may recur under stress.

BODY DYSMORPHIC DISORDER

Body dysmorphic disorder (BDD) is a mental health problem in which a person is excessively concerned about a perceived defect in his or her appearance and this preoccupation with body image causes significant distress.

The cause of body dysmorphic disorder is unclear, although it is thought to be due to a combination of several factors, possibly including low levels of serotonin. It may occur in combination with other disorders, such as eating disorders, obsessive-compulsive disorder, and generalized anxiety disorder, although it is not clear whether there is a causative relationship with such disorders.

Many people are dissatisfied with some aspect of their appearance, but people with BDD are obsessed with one or more perceived flaws. Typical signs of BDD include refusing to be in photographs; trying to hide the “flaw” with clothing or makeup; constantly checking one's appearance in mirrors; frequently comparing one's appearance with that of others; often seeking reassurance about one's appearance; frequently touching the perceived flaw; and picking the skin to make it smooth. In addition, a person may feel anxious and self-conscious around other people because of the perceived flaw and may avoid social situations in which it might be noticed. In some cases, medical and surgical treatment may be sought to correct the perceived flaw.

Diagnosis

Body dysmorphic disorder is diagnosed by psychiatric evaluation. To be diagnosed with this disorder, preoccupation with appearance must cause considerable distress and interfere with everyday life.

SOMATIZATION DISORDER

In this psychological problem, a person complains of physical symptoms for which no underlying physical cause is found.

A person with this disorder typically experiences several physical symptoms that persist for years. The symptoms are not generated intentionally and are often severe enough to interfere with everyday life, but no physical cause for them can be identified. The symptoms may affect any part of the body, but complaints involving the digestive, nervous, and reproductive systems are the most common. If symptoms involve the voluntary central nervous system, such as paralysis, the condition is sometimes classed as conversion disorder (formerly known as hysteria).

The cause of somatization disorder is not known. In some cases it may be associated with other disorders such as anxiety and depression, but it is not clear whether these are causes or effects of the disorder.

HYPOCHONDRIA

This disorder is characterized by excessive and unrealistic anxiety about having a serious illness.

In hypochondria (also known as hypochondriases) trivial symptoms assume unrealistic significance. The symptoms are real, such as a cough or headache, but people with hypochondria are genuinely worried that they indicate a serious disease, such as lung cancer or a brain tumor. In mild forms, the person may simply worry constantly. In more severe cases, hypochondria can seriously disrupt everyday life, with the person making frequent visits to the doctor to have tests. Even when the test results prove negative, people may remain convinced that they have a serious illness and often seek other medical opinions. In addition, the person may believe they have a particular disease after hearing about it; for example, after hearing about Alzheimer's disease, an instance of momentary forgetfulness might lead the person to believe they have that disease. Many people with hypochondria also have other mental health disorders, such as depression, obsessive-compulsive disorder, phobia, or generalized anxiety disorder.

MUNCHAUSEN'S SYNDROME

Sometimes also known as hospital addiction syndrome, Munchausen's syndrome is a rare psychiatric condition in which a person repeatedly seeks medical attention for faked or self-induced symptoms of illness.

People with Munchausen's syndrome are aware that they are fabricating symptoms, unlike those with hypochondria, who truly believe they are ill. They do not fake illness in order to receive tangible benefits (such as financial gains). Instead, the motive seems to be to obtain investigation, treatment, and attention from medical personnel. People with the syndrome often have a good

medical knowledge and create plausible symptoms and explanations for their faked illness, which makes diagnosis of Munchausen's syndrome very difficult. In addition to lying about symptoms, they may try to manipulate test results – for example, by adding blood to a urine sample – and may even inflict symptoms on themselves; they may injure themselves or ingest poisons, for instance. Typically, they attend many different hospitals, often repeatedly presenting the same symptoms. In a related condition, known as Munchausen's by proxy or fabricated and induced illness (FII), people may invent or induce symptoms in somebody else. This usually involves parents taking or inducing symptoms in their child.
Diagnosis is difficult and involves carrying out various tests to exclude an underlying illness. If a genuine underlying cause is not found, a diagnosis is made from a psychiatric assessment.

TOURETTE'S SYNDROME

Tourette's syndrome is a neurological disorder that is characterized by sudden, repetitive, involuntary movements (called motor tics) and noises or words (called vocal tics).

In most cases, Tourette's syndrome runs in families and genetic factors may be involved, although the relevant genes and the mode of inheritance have not been identified. In some cases, known as sporadic Tourette's syndrome, there is no apparent inherited link. Various brain abnormalities have been implicated, including malfunctioning of the basal ganglia, thalamus, and frontal cortex, and abnormalities in the neurotransmitter serotonin, dopamine, and norepinephrine, although their causative relationship to Tourette's has not been established. Environmental factors may also play a role in the development of Tourette's syndrome.

Symptoms and effects

The characteristic symptoms of Tourette's syndrome are motor tics, such as blinking, facial twitches, shoulder shrugging, and head jerking, and vocal tics, such as grunting or repeating words. The involuntary utterances of swear words (coprolalia) is well-known feature, but is comparatively rare. Other metal health problems, such as depression or anxiety disorders, may also develop. Typically, the symptoms first appear during childhood and get worse during the teenage years but then improve. However, in some cases the condition get progressively worse and lasts throughout adulthood.

Diagnosis

For a positive diagnosis of Tourette's, both motor and vocal tics must be present and they must not be due to another medical condition, medications, or other substances. They must occur several times a day or most days or intermittently for more than a year.

SCHIZOPHRENIA

A serious mental health disorder, schizophrenia is characterized by distortions in thinking, perceptions of reality, expression of emotions, social relationships, and behavior.

Contrary to popular belief, schizophrenia is not a "split personality," but rather a form of psychosis in which a person is not able to distinguish what is real from what is imagined.

The cause of schizophrenia is not known, although it is believed to result from a combination of genetic and environmental factors. Schizophrenia runs in families, and a person who has a close family member with the disorder is at increased risk of developing it. However, it is believed that genetic susceptibility alone is insufficient to cause schizophrenia and environmental factors are also necessary. Among the environmental factors that may be involved are exposure to infection or malnutrition before birth, stressful life events, and the use of marijuana. Excess dopamine levels may also be involved since all antipsychotic drugs block dopamine, and drugs that release dopamine can trigger schizophrenia. Various brain abnormalities have been identified in people with schizophrenia including unusually low levels of glutamate receptors and a reduction of gray matter in certain brain regions, notably the hippocampus, frontal lobes, and temporal lobes. However, the significance of these abnormalities in schizophrenia has not been established.

Symptoms and treatment

Schizophrenia can take various forms. The symptoms typically develop during late adolescence or early adulthood in men, and some 4-5 years later in women. Different individuals may have different patterns of symptoms, and with varying degrees of severity. However, in general they may include delusions; hallucinations, especially auditory ones; jumbled, incoherent speech (so-called "word salad"); lack of emotions or inappropriate emotions, such as amusement at bad news; disorganized thoughts; clumsiness; involuntary or repetitive movements; social isolation; neglect of personal health and hygiene; and unresponsive (catatonic) behavior.

Schizophrenia is diagnosed from the symptoms, but various tests are also usually performed to exclude other possible causes of abnormal behavior. Treatment is with medication, such as antipsychotic drugs, and talking therapy. About 1 in 5 people make a full recovery, but for the remainder schizophrenia is lifelong.

DELUSIONAL DISORDER

This disorder is a type of psychosis characterized by the presence of persistent, irrational beliefs that are not caused by another mental disorder.

In delusional disorder, the delusions are "non-bizarre" (involving things that are within the realms of possibility). Apart from the delusion and behavior related to it, someone with the disorder often functions normally, although preoccupation with the delusion can disrupt everyday life. The cause of delusional disorder is not known, but it is more common in people with family members who have this disorder or schizophrenia. Socially isolated people tend to be more susceptible, and in some cases it may also be triggered by stress.

There are several types of delusional disorder; jealous (the delusion that their partner is unfaithful); persecutory (a belief that somebody is hounding or trying to harm them); erotomanic (somebody – often a celebrity – is n love with them); grandoise (an inflated sense of worth, power, talent, or knowledge); somatic (the delusion that they have a physical defect or medical problem); and mixed (two or more of the other delusional types).

ADDICTIONS

An addiction is a state of being so dependent on something that it becomes difficult or impossible to do without it for any significant period.

It is possible to become addicted to anything, but whatever the addiction is, the person cannot control it. An addiction may be to a substance or an activity.

It is believed that addictive substances or activities affect the brain so that it reacts in the same way that it responds to pleasurable experiences, by increasing the release of the neurotransmitter dopamine. It is not known why some people seem to be more likely to become addicted than others, although it is thought that genetic susceptibility and environmental factors probably play a role. For example, children who grow up in a family where there is drug or alcohol abuse are more likely to become addicted.

Although some symptoms are specific to the addictive substance or activity, there are several general symptoms that occur in all addictions. These include the development of tolerance – the need for increasing amounts to produce the desired effect; unpleasant physical and/or psychological withdrawal symptoms when the substance or activity is stopped; and continuing to use the substance or engage in the activity even though tit may be detrimental to physical or mental health, or relationship.

PERSONALITY DISORDERS

This is a group of disorders in which a person's habitual behavior and thought patterns cause recurrent problems in everyday life.

The cause of personality disorders is not known but they are thought to be due to a combination of genetic and environmental influences. Factors that may increase the risk of developing a personality disorder include a family history of such disorder or another mental illness; abuse during childhood; a dysfunctional family life during childhood; and having conduct disorder in childhood.

There are many types of personality disorders, but in general they are all characterized by an inflexible way of thinking and behaving, irrespective of the situation. Symptoms tend to develop in adolescence or early adulthood and may vary in severity. Often a person with a personality disorder is not aware that the behavior and thought patterns are inappropriate, but may be aware of problems with personal, social, or work relationships, and these problems may cause distress. Specific symptoms depend on the type of personality disorder a person has.

EATING DISORDERS

An eating disorder is a condition in which there are extreme preoccupations with food and/or weight and disturbances in eating behavior.

The causes of eating disorders are not clear, although a combination of biological, genetic, psychological, and social factors are thought to be involved. The effects of social and peer pressure to be think may be a contributory factor. Anxiety about body image, low self-esteem, and depression may also be involved.

Types of eating disorders

Eating disorders are most common in adolescent girls and young women, but also affect older women and men. The most common types are anorexia nervosa, bulimia nervosa, and binge-eating disorder. Anorexia nervosa is is characterized by self-starvation and excessive weight loss. Its main features are an intense fear of being fat or gaining weight; a resistance to maintaining normal weight; and the denial of the seriousness of low body weight. It can be fatal.

Bulimia nervosa is characterized by binge eating and then repeated compensatory actions to prevent weight gain, such as self-induced vomiting, laxative or diuretic use, excessive exercise, or fasting. It can result in life-threatening heart abnormalities due to an imbalance of electrolytes.

Binge-eating disorder is similar to bulimia nervosa but without the compensatory actions to counter the binges, which can lead to obesity.

ATTENTION DEFICIT HYPERACTIVITY DISORDER

Commonly known as ADHD, attention deficit hyperactivity disorder is one of the most common behavioral disorders of childhood.

ADHD is characterized by persistent difficulty paying attention and/or hyperactivity. It is most common in children, but it may persist into adulthood. ADHD tends to run in families and in most cases genetic inheritance, probably involving many genes, is thought to be the most probably underlying cause. However, this genetic predisposition interacts with various other factors, such as exposure to certain toxins, (such as nicotine and alcohol) before birth, brain damage before birth or in the early years of life, and food allergies. There is no evidence that parenting problems cause ADHD, but they may influence its severity and a child's coping strategies. Some brain abnormalities have been found in children with ADHD, including low dopamine levels drugs that increase dopamine levels in the brain, such as Ritalin, may lessen symptoms. Symptoms usually appear during early childhood and may become worse when the child starts school. Due to the various ADHD-related problems, there may also be difficulty making friends, low self-esteem, anxiety, or depression.

DEVELOPMENTAL DELAY

Developmental delay is a term used when a baby or young child has not acquired the skills and abilities normally achieved by a particular age.

In the few first years of life there are important stages – developmental milestones – when a child is normally expected to have acquired certain basic physical, mental, social, and language skills. Child development is assessed in several areas, including physical and motor development; vision, hearing, speech, and mental development; and social development.

Generalized or specific delay

Delays can vary in severity and may affect one or more areas of development. Generalize delay affects most areas of development and may be due to various factors, such as severe visual or hearing impairment; brain damage; learning difficulties; Down syndrome; severe, prolonged disease, such as heart disease, muscle disease, or a nutritional disorder; or a lack of physical, emotional, or mental stimulation.

Developmental delay may also occur in specific areas only . Delay in movement and walking is quite common, and often a child catches up. However, there may be serious underlying cause such as muscular dystrophy, cerebral palsy, or a neural-tube defect. Delay in speech and language development may have various causes, including lack of stimulation, hearing problems, or more rarely, autism. Generalized difficulty with muscle control that affects speaking, which may be due to cerebral palsy, for example, can also cause delay in this area.

Diagnosis and treatment

Often delays are first noticed by parents, but a delay may also be detected during routine developmental checks. If a problem is suspected, a full developmental assessment is done, and the child may be referred to a specialist. Treatment depends on the severity and type of delay. It may include physical aids, such as glasses or hearing aids, therapies such as speech therapy, and possibly special educational help.

LEARNING DISABILITY

Learning disability refers to problems in understanding, remembering, using or responding to information.

There are differences in opinion about what the term "learning disability" encompasses but, in general, it applies to conditions in which there is developmental delay. However, learning difficulty may also refer to a specific difficulty, for example, in reading or writing.

Types

Learning disabilities are commonly categorized as generalized or specific. Generalized learning disability affects all or almost all intellectual functions, leading to developmental delay. In addition to below-average intelligence, there may also be behavioral problems and, in severe cases, physical developmental problems, as well, impairing motor skills and coordination. Specific learning disabilities affect only one or a few areas of mental functioning and, in many cases, intelligence is not impaired.

People with learning disability may also have various associated conditions, such as ADHD, autistic disorder, or epilepsy.

Causes

Learning disability can have a wide of causes, including genetic abnormalities, such as Williams syndrome, or chromosomal abnormalities, such as Down syndrome and fragile X syndrome. Other factors include problems with brain development before or during birth, possibly due to exposure to toxins such as alcohol or drugs in the uterus, lack of oxygen, or premature or prolonged labor; and a head injury, malnutrition, or exposure to environmental toxins, at a young age.

If a learning disability is suspected, a developmental assessment will be carried out. Hearing, vision, and other medical and genetic tests will also be done to check for underlying physical causes of the learning difficulties.

CONDUCT DISORDER

Conduct disorder is a behavioral disorder in which a child or adolescent repeatedly and persistently behaves in a way that is antisocial.

Various factors put a child at increased risk of conduct disorder, including genetic factors, an unstable and/or violent family life, lack of supervision, abuse, and bullying. Learning disabilities, attention deficit hyperactivity disorder, and mental health problems such as depression also increase the risk. Children with conduct disorder also tend to have abnormal responses to reward and punishment.

Symptoms and effects

Symptoms vary from individual to individual, but they include aggressive behavior, physical cruelty, theft or persistent lying, deliberate destruction of property, and violations of rules, such as playing truant from school. In some cases, a child may also engage in alcohol or drug abuse. Many children act in an antisocial or disruptive way from time to time, but in a child with conduct disorder the behavior occurs repeatedly over a period of several months or longer. As a result of

such behavior, a child may find it difficult to make friends, have low self-esteem, and do poorly in school.
A diagnosis is usually based on a psychiatric assessment of the child's behavior patterns. Treatment of conduct disorder, through talking therapies such as cognitive-behavioral therapy, can be difficult, but early treatment is more likely to be effective. It is important that parents are involved in the treatment.

AUTISM SPECTRUM DISORDERS

This is a group of developmental disorders characterized by problems with communication, social relationships, and repetitive behavior.

There are several types of autism spectrum disorders, but the main ones are autistic disorders (sometimes referred to as "classic" autism) and Asperger's syndrome.
Autistic disorder usually appears in early childhood, before the age of about three years. It produces problems in three main developmental areas: impaired social skills, impaired communication, and restricted behavior. Typically, such children fail to respond to their name or to other speech directed at them; avoid eye contact; resist physical contact; start talking late and speak with an abnormal tone or rhythm; show abnormal response to social cues, such as faces and voices; perform repetitive movements, such as rocking; develop specific routines and become disturbed when they are changed; and may be unusually sensitive to sound, light, and touch, but sometimes ignore sensory signals. About half of all children with autistic disorder have learning difficulties and some children develop seizures. However, some children with autism have a high ability in one area, such as rote memory or precocious reading, and, rarely a child may have an exceptional ability in a specific area (called savant syndrome), such as mathematics. Children with Asperger's syndrome tend to have similar symptoms, but in a less severe form. Many children are of average or above average intelligence and develop speech and language skills at the normal age. However, they have very narrow interests, find it difficult to interact socially with their peers, and are usually inflexible in their behavior and routines.
There is no cure for autism spectrum disorders, and treatment is based on supportive education to help a child reach his or her potential.

THE END