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Understanding the Brain: The Birth of a Learning Science

PART I

Chapter 1

An "ABC" of the Brain

The only good is knowledge and the only evil is ignorance.

Socrates

Not to know is bad. No to wish to know is worse.

(*African Proverb*)

Chapter 1 provides an "ABC" of the contents of the report by listing keywords and concepts in alphabetical order covered in the chapters to follow. It begins with **A***cquistion of knowledge and* **B***rain, and runs through to* **V***ariability,* **W***ork and* **XYZ**. *The reader can choose a particular topic of interest, and the corresponding description points to the relevant chapter(s) which provide more in-depth coverage of the issue. This chapter is relevant for all those who are interested in the issue of "learning sciences and brain research" including learners, parents, teachers, researchers and policy makers.*

Acquisition of knowledge

The neuroscientific approach to learning provides a hard-scientifically based theoretical framework for educational practices. This rapidly emerging field of study is slowly but surely building the foundations of a "Science of Learning".

A living being is made up of various levels of organisation. The result is that a single human process may be defined differently depending on the level used as a reference. This is true of the learning process where the definition varies depending on the perspective of the person who describes it.

The differences between cellular and behavioural definitions reflect the contrasting views of neurosciences and educational sciences. Neuroscientists consider learning as a cerebral process where the brain reacts to a stimulus, involving the perception, processing and integration of information. Educators consider this as an active process leading to the acquisition of knowledge, which in turn entails lasting, measurable and specific changes in behaviour.

Brain

Even though it plays a fundamental role, the brain remains one single part of a whole organism. An individual cannot solely be reduced to this organ as the brain is in constant interaction with other parts of the human body.

The brain is the seat of our mental faculties. It assumes vital functions by influencing heart rate, body temperature, breathing, etc., as well as performing so-called "higher" functions, such as language, reasoning and consciousness.

This organ includes two hemispheres (left and right), with each further divide into lobes (occipital, parietal, temporal and frontal) – further described in Chapter 2.

The main components of cerebral tissue are glial and nerve cells (neurons). The nerve cell is considered as the basic functional unit of the brain because of its extensive interconnectivity and because it specialises in communication. Neurons are organised in functional networks that are situated in specific parts of the brain.

Cognitive functions

Having been studied at various levels, cognitive functions benefit from a rich multidisciplinary research effort. Therefore, in a complementary way, neurosciences, cognitive neuroscience and cognitive psychology seek to understand these processes.

Cognition is defined as the set of processes enabling information processing and knowledge development. These processes are called "cognitive functions". Among these, the higher cognitive functions correspond to the human brain's most elaborate processes. They are the product of the most recent phase of the brain's evolution and are mainly centred in the cortex, which is a particularly highly developed structure in humans (see Chapter 2).

Examples of these functions are certain aspects of perception, memory and learning, but also language, reasoning, planning and decision-making.

Development

The brain is continually changing – developing – throughout life. This development is guided by both biology and experience (see Chapter 2). Genetic tendencies interact with experience to determine the structure and function of the brain at a given point in time. Because of this continuous interaction, each brain is unique.

Though there is a wide range of individual differences in brain development, the brain has age-related characteristics that can have important consequences for learning. Scientists are beginning to map out these maturational changes and to understand how biology and experience interact to guide development.

Understanding development from a scientific perspective could powerfully impact educational practice. As scientists uncover age-related changes in the brain, educators will be able to use this information to design didactics that are more age-appropriate and effective.

Emotions

Emotional components have long been neglected in institutional education. Recent contributions of neuroscientists are helping to remedy this deficiency by revealing the emotional dimension of learning (see Chapter 3).

As opposed to "affect", which is their conscious interpretation, emotions arise from cerebral processes and are necessary for the adaptation and regulation of human behaviour.

Emotions are complex reactions generally described in terms of three components: a particular mental state, a physiological change and an impulsion to act. Therefore, faced with a situation perceived as dangerous, the reactions engendered will simultaneously consist of a specific cerebral activation of the circuit devoted to fear, body reactions typical of fear (*e.g.* accelerated pulse, pallor and perspiring) and the fight-or-flight reaction.

Each emotion corresponds to a distinct functional system and has its own cerebral circuit involving structures in what we call the "limbic system" (also known as the "seat of the emotions"), as well as cortical structures, mainly the prefrontal cortex which plays a prime role in regulating emotions. Incidentally, the prefrontal cortex matures particularly late in human beings, concluding its development in the third decade of an individual's development. This means that cerebral adolescence lasts longer than was, until recently, thought, which helps to explain certain features of behaviour: the full development of the prefrontal cortex, and therefore the regulation of emotions and compensation for potential excesses of the limbic system, occur relatively late in an individual's development.

Continual exchanges make it impossible to separate the physiological, emotional and cognitive components of a particular behaviour. The strength of this interconnectivity explains the substantial impact of emotions on learning. If a positively perceived emotion is associated with learning, it will facilitate success, whereas a negatively perceived emotion will result in failure.

Functionality, neural base of learning

The neuroscientific definition of learning links this process to a biological substrate or surface. From this point of view, learning is the result of integrating all information perceived and processed. This integration takes form in structural modifications within

the brain. Indeed, microscopic changes occur, enabling processed information to leave a physical "trace" of its passage.

Today, it is useful, even essential, for educators and anyone else concerned with education to gain an understanding of the scientific basis of learning processes.

Genetics

The belief that there is a simple cause and effect relationship between genetics and behaviour often persists. Imagining a linear relationship between genetic factors and behaviour is only a short step away from full-blown determinism. A gene does not activate behaviour but instead consists of a sequence of DNA containing the relevant information to produce a protein. The expression of the gene varies on the basis of numerous factors, especially environmental factors. Once a protein is synthesised in the cell, it occupies a specific place and plays a role in the functioning of this cell. In this sense, it is true that if genes affect function, they consequently mould behaviour. However, this is a complex non-linear relationship with the various levels of organisation influencing one another.

As research slowly but surely advances, belief in a frontier between the innate and the acquired is disappearing, giving way to understanding the interdependence between genetic and environmental factors in brain development.

To predict behaviour on the basis of genetics will be incomplete: any approach solely influenced by genetics is not only scientifically unfounded but also ethically questionable and politically dangerous.

"Hands on" and Holistic – learning by doing

"I hear and I forget,
I see and I remember,
I do and I understand"

Confucius

Long forgotten by educators, this quote regained prominence in the 20th century with the advent of constructivism. Contrary to theories focused on expert educators who transmit knowledge, this current advanced a new concept of learning: the construction of knowledge. Learning becomes learner-centred and relies on the development of prior knowledge, based on the experience, desires and needs of each individual.

Therefore, this theoretical upheaval has given rise to the so-called active or experiential practices of "learning-through-action". The objective is to actively involve learners in interacting with their human and material environment, based on the idea that this will lead to a more profound integration of information than perception. Action necessarily implies operationalisation – the implementation of concepts. The learner not only needs to acquire knowledge and know-how, but must also be able to render them operational in real applications. Therefore the learner becomes "active", implying a better level of learning.

Not all neuroscientific discoveries give rise to innovations in terms of didactics. However, they provide a solid theoretical basis for well-tried practices which have been consolidated through experience. These scientific insights then serve to underpin the body of empirical and intuitive knowledge already accumulated, and explain why some practices fail or succeed.

Intelligence

The concept of intelligence has always been a subject of controversy. Can a single concept account for all of the intellectual faculties of an individual? Can these faculties be separated and measured? And in particular, what do they show and predict about the cerebral functioning of an individual and about social behaviour?

The notion of intelligence evokes "skills", whether they are verbal skills, spatial skills, problem-solving skills or the very elaborate skill of dealing with complexity. However, all of these aspects neglect the concept of "potential". Yet, neurobiological research on learning and cognitive functions clearly shows that these processes undergo constant evolution and are dependent on a number of factors, particularly environmental and emotional ones. This means that a stimulating environment should offer each individual the possibility to cultivate and develop his/her skills.

From this point of view, the many attempts to quantify intelligence using tests (such as IQ measurements or others) are too static and refer to standardised and culturally (sometimes even ideologically) biased faculties.

Based on a priori *assumptions, intelligent tests are restrictive and therefore problematic. Based on this "intelligence calculation" or the debatable assignation of individuals to different levels of intelligence, what should be concluded for the practices or even the choices related to career orientation?*

Joy of learning

"Tell me and I forget
Teach me and I remember
Involve me and I learn"

Benjamin Franklin

This maxim restores involvement to its role as an essential condition of significant learning. Involvement can be summed up as the commitment of an individual within a given action. In this sense, it results directly from the process of motivating the individual to behave in a certain way or to pursue a particular goal. This process can be triggered by internal or external factors. This is why we speak of intrinsic motivation, which solely depends on the learner's own needs and desires, or extrinsic motivation, which takes into account external influences on the individual. Motivation is largely conditioned by self-assurance, self-esteem and by the benefits the individual may accrue in terms of a targeted behaviour or goal.

The combination of motivation and self-esteem are essential to successful learning. In order to give these factors their rightful place within learning structures, the system of tutoring is gaining ground. It offers the learner personalised support and is better adapted to his/her needs. A more personal climate for learning serves to motivate learners but should not disregard the crucial role of social interactions in all modes of learning. Personalisation should not mean the isolation of learners.

Motivation has a pivotal role in the success of learning, especially intrinsic motivation. The individual learns more easily if s/he is doing it for him/herself, with the desire to understand.

Although it is currently difficult to construct educational approaches that could go beyond "carrot and stick" systems and target this intrinsic motivation, the benefits of this approach are such that it is of paramount importance for research to orient its efforts towards this domain.

Kafka

By describing in "The Castle" the vain efforts of the protagonist to attain his objectives ("There is a goal, but no way": "Es gibt zwar ein Ziel, aber keinen Weg zum Ziel"), Franz Kafka relates the feeling of despair that an individual can feel when being confronted with a deaf and blind bureaucratic machine. Reminiscent of this work, Dino Buzzati's story "K" is a tragedy of a misunderstanding, emphasising how sad, but also dangerous it can be to understand certain realities too late…

There is abundant resistance to taking on board neuroscientific discoveries for educational policies and practices, sufficient to discourage even the most fervent advocates. The reasons may be various – simple incomprehension, mental inertia, the categorical refusal to reconsider certain "truths", through to corporate reflexes to defend acquired positions, even staunch bureaucracy. The obstacles are numerous to any trans-disciplinary effort to create a new field, or even more modestly to shed new light on educational issues. This poses a delicate problem of "knowledge management". Even if some constructive scepticism can do no harm, every innovative project finds itself in the position of "K" at one point or another, seeking to reach the Castle. Despite such difficulties, a way exists; to quote Lao Tzu: "The journey is the destination."

Moreover, neuroscience unintentionally generates a plethora of "neuromyths" founded on misunderstandings, bad interpretations, or even distortions of research results. These neuromyths, which become entrenched in the minds of the public by the media, need to be identified and dispelled. They raise many ethical questions which in democratic societies need to be addressed through political debate.

We can ask whether (in the mid-term at least), it is acceptable, in any reflection about education, not to take into consideration what is known about the learning brain. Is it ethical to ignore a field of relevant and original research that is shedding new light and fundamental understanding on education?

Language

Language is a specifically human cognitive function which is also dedicated to communication. It opens up the use of a system of symbols. When a finite number of arbitrary symbols and a set of semantic principles are combined according to rules of syntax, it is possible to generate an infinite number of statements. The resulting system is a language. Different languages use phonemes, graphemes, gestures and other symbols to represent objects, concepts, emotions, ideas and thoughts.

The actual expression of language is a function that relates at least one speaker to one listener, and the two can be interchangeable. This means language can be broken down into a direction (perception or production) and also into a mode of expression (oral or written). Oral language is acquired naturally during childhood by simple exposure to spoken language; written language, on the other hand, requires intentional instruction (see Chapter 4).

Language was one of the first functions to be shown to have a cerebral basis. In the 19th century, studies of aphasia by two scientists (Broca and Wernicke) revealed that certain areas of the brain were involved in language processing. Since then, studies have confirmed that these areas belong to the cerebral circuits involved in language (see Chapter 4).

Accumulating a large body of neuroscientific knowledge on language was possible because of neuroscience's major interest in this function. The understanding of language mechanisms and how they are learned has already had an important impact on educational policies.

Memory

During the learning process, traces are left by the processing and integration of perceived information. This is how memory is activated. Memory is a cognitive process enabling past experiences to be remembered, both in terms of acquiring new information (development phase of the trace) and remembering information (reactivation phase of this trace). The more a trace is reactivated, the more "marked" memory will be. In other words, it will be less vulnerable and less likely to be forgotten.

Memory is built on learning, and the benefits of learning persist thanks to it. These two processes have such a profound relationship that memory is subject to the same factors influencing learning. This is why memorisation of an event or of information can be improved by a strong emotional state, a special context, heightened motivation or increased attention.

Learning a lesson too often means being able to recite it. Training and testing are usually based on retrieving and therefore on memorising information often to the detriment of mastering skills and even of understanding content. Is this role given to memory skills in learning justified? This is a pivotal question in the field of education, and is beginning to attract the attention of neuroscientists.

Neuron

Organised in extensively interconnected networks, neurons have electrical and chemical properties that enable them to propagate nerve impulses (see Chapter 2, especially Figure 2.1). An electrical potential is propagated within a nerve cell and a chemical process transmits information from one cell to another. These nerve cells are consequently specialised in communication.

The electrical propagation within the cell is uni-directional. Inputs are received by the neuron's dendrites or the cell body. In response to these inputs, the neuron generates action potentials. The frequency of these potentials varies according to these inputs. Therefore, the action potentials propagate through the axon.

A zone called the *synapse* serves as a junction between two neurons. The synapse consists of three components: the axon ending, the synaptic gap and the dendrite of the postsynaptic neuron. When the action potentials reach the synapse, it releases a chemical substance called the neurotransmitter, which crosses the synaptic gap. This chemical activity is regulated by the type and amount of neurotransmitters, but also by the number of receptors involved. The amount of neurotransmitters released and the number of receptors involved are responsive to experience, which is the cellular basis of plasticity (see below). The effect on postsynaptic neurons may be excitatory or inhibitory.

Therefore, this combination of electrical and chemical activity of the neurons transmits and regulates information within the networks formed by neurons.

In order to improve the understanding of cerebral activity, various functional imaging technologies (fMRI, MEG, PET, OT, etc.) (see Annex B) are used to visualise and study the activity of the changes in blood flow induced by neuronal activities.

Studies localising cerebral networks open an important door to our understanding of learning mechanisms. The better the temporal and spatial resolution, the more precise the localisation and consequently the better our understanding of cerebral function.

Opportunity windows for learning

Certain periods in an individual's development are particularly well-suited to learning certain skills. During these key moments the brain needs certain types of stimulations in order to establish and maintain long-term development of the structures involved. These are the stages at which the individual's experience becomes an overriding factor, responsible for profound changes.

These periods are called "sensitive periods" or windows of opportunity, because they are the optimum moments for individuals to learn specific skills. They are part of natural development, but experience is needed so that a change (learning) can be effective. This process can be described as "experience-expectant" learning, such as oral language (see Chapter 4). It is not the same as "experience-dependent" learning such as written language, which can take place at any moment in an individual's lifetime.

If learning does not occur in these windows of opportunity, it does not mean it cannot occur. Learning takes place throughout a whole lifetime although outside these windows of opportunity, it takes more time and cognitive resources and it will often not be as effective.

A better understanding of sensitive periods and the learning that occurs during those periods is a crucial avenue of future research. An increasingly complete map will enable us to better match instruction to the appropriate sensitive period in educational programmes with a corresponding positive impact on the effectiveness of learning.

Plasticity

The brain is capable of learning because of its flexibility (see Chapter 2). It changes in response to stimulation from the environment. This flexibility resides in one of the intrinsic properties of the brain – its plasticity.

The mechanism operates in various ways at the level of the synaptic connections (Figure 2.1). Some synapses may be generated (synaptogenesis), others eliminated (pruning), and their effectiveness may be moulded, on the basis of the information processed and integrated by the brain.

The "traces" left by learning and memorisation are the fruit of these modifications. Plasticity is consequently a necessary condition for learning and an inherent property of the brain; it is present throughout a whole lifetime.

The concept of plasticity and its implications are vital features of the brain. Educators, policy makers and all learners will all gain from understanding why it is possible to learn over a whole lifetime and indeed brain plasticity provides a strong neuroscientific argument for "lifelong learning". Would not primary school be a good place to start teaching learners how and why they are capable of learning?

Quality existence and healthy living

Like any other organ in the human body, the brain functions best with healthy living. Recent studies have looked into the impact of nutrition and physical activity on cerebral faculties and particularly on learning. Results show that a balanced diet contributes to the development and functioning of the brain, while also preventing some behavioural and

learning problems (see Chapter 3). In the same respect, regular physical activity has a positive effect on the functioning of human cognition, modifying the activity in certain regions of the brain.

Sleep is also a determining factor in brain development and function (Chapters 3 and 6). Anyone who has lacked sleep knows that cognitive functions are the first to suffer. It is during sleep that some of the processes involved in plasticity and consolidation of knowledge take place, processes that consequently play a pivotal role in memorising and learning.

Environmental factors (noise, ventilation, etc.) and physiological factors (diet, exercise, sleep, etc.) influence learning. In the short run, advances in this area should lead to concrete applications in terms of school and educationally-related practices.

Representations

Human beings are constantly perceiving, processing and integrating information, *i.e.* they learn. Individuals have their own representations, which gradually build up on the basis of their experience. This organised system translates the outside world into an individual perception. An individual's system of representation governs his/her thinking processes.

Since Plato's Cave, philosophy has pondered the question of representations. Evidently, the objective here is not to respond to the eternal questions of humanity, although it is not impossible that one day our knowledge of brain functioning is such that it will bring about new elements to these eternal philosophical debates.

Skills

The term "skills" is frequently used in English when behaviour and learning are being discussed. A given behaviour can be broken down into skills, understood as the "natural units" of behaviour.

Language, for instance, can be broken down into four "meta-skills" according to transmission or reception and the means of communication. These meta-skills are oral understanding, oral production, reading and writing. Each of these meta-skills in turn can be further broken down into more distinct skills. Oral understanding, for example, consists of some ten skills, which include short term memorisation of series of sounds, discrimination of a given language's distinctive sounds, and distinction of words and identification of grammatical categories.

Each skill corresponds to a specific class of activities. This raises questions about evaluating individual progress and the distinction between skills and knowledge. What do we expect of children? Skills or knowledge? What do we want to "measure" when we test children?

Team and social interactions

Social interactions catalyse learning. Without this sort of interaction, an individual can neither learn nor properly develop. When confronting a social context an individual's learning improves in relation to the wealth and variety of that context.

Discovery triggers the processes of using and building knowledge and skills. Dealing with others enables individuals to develop strategies and refine their reasoning. This is why social interaction is a constituent condition both for early development of cerebral structures and for the normal development of cognitive functions (see Chapter 3).

What place do schools leave for interaction between learners? The appearance of new technologies in the educational sector has had far-reaching repercussions on interactivity in learning situations. What will be the impact of these changes on learning itself?

These questions are being addressed by the rapidly emerging field of social neuroscience, which deals with social processes and behaviour.

Universality

Numerous features characterise the human kind, the development of the brain being one of them. It follows a programme recorded in the genetic heritage of each individual, and is programmed as part of a "ballet" where perfectly regulated genes are constantly nourished by experience.

One of the intrinsic properties of the brain is its plasticity (see Chapter 2). The brain continually perceives, processes and integrates information derived from personal experience, and therefore undergoes changes in the physical connections within its networks of neurons. This continual development is the result of the brain's normal operation and implies a permanent learning capacity. This means that development is a constant and universal feature of cerebral activity and that a human being can learn throughout the lifespan.

"Everyone has the right to education" (Universal Declaration of Human Rights, United Nations, 10 December 1948, Article 26). Education regulates learning so that everyone has access to the fundamentals of reading, writing and arithmetic (see Chapters 4 and 5).

International evaluations are performed to check the equality and durability of the various educational systems. Although it is difficult to "measure" acquired knowledge across cultural borderlines, such evaluations heighten awareness of the need for constant improvement in education.

Variability

Experience plays a fundamental role in individual development and the make-up of a human being, but it remains personal and subjective. Representations resulting from experience are consequently different from one person to another. Experience also plays a major role in building preferential styles, leading the learner to use particular learning strategies according to the situation.

Specific learning causes changes – transitions from one state to another. Yet, the diversity of personal experience and representations implies different conditions at the outset for each person. In addition, modifications resulting from learning vary according to learning motivations, interactions and strategies. This is why the impact of instruction differs from one person to another, and why we speak of variability.

Students in the same class, taking the same course will not learn the same things. Their representations of the concepts presented will vary as they do not all start with the same basic knowledge nor the same mode of learning. The result is that their representations will not develop in the same manner. They will all maintain traces of this learning experience, but these traces will be different and specific to each individual.

Learning experiences need to take into account individual differences, so that diversification of the curriculum to accommodate them is an increasingly important educational goal.

The question of cortical differences between men and women is frequently raised. As yet, neuroscientific data neither confirm nor disprove this conjecture.

Work

A lot of work has been done and a major task has been achieved in recent years to develop educational neuroscience, and this is helping give birth to a still larger, trans-disciplinary learning science (see Chapter 7). These achievements will seem small, however, in comparison with what is still to come from those who follow us into this field. One can hope that they will meet fewer barriers, especially as they will have to deal with a much larger knowledge base. For it happens that…

… XYZ

… the story is far from ended. This CERI project is merely the beginning of an adventure and it is now up to others to take up the baton. Many have already engaged on such ways (see Chapter 7). There is much more than these three remaining letters to write into our brain alphabet. Our knowledge of the brain is like the brain itself: a continual evolution…

Glossary

Acalculia. See dyscaculia.

Accumbens area. See nucleus accumbens.

Action potential. This occurs when a neuron is activated and temporarily reverses the electrical state of its interior membrane from negative to positive. This electrical charge travels along the axon to the neuron's terminal where it triggers the release of an excitatory or inhibatory neurotransmitter.

Activation study. Study performed with imaging techniques (see also PET and fMRI).

ADHD (Attention Deficit Hyperactivity Disorder). A syndrome of learning and behavioural problems characterised by difficulty sustaining attention, impulsive behaviour (as in speaking out of turn), and hyperactivity.

Alzheimer's disease. A progressive degenerative disease of the brain associated with ageing, characterised by diffuse atrophy throughout the brain with distinctive lesions called senile plaques and clumps of fibrils called neurofibrillary tangles. Cognitive processes of memory and attention are affected (see also neurodegenerative diseases).

Amygdala. A part of the brain involved in emotions and memory. Each hemisphere contains an amygdale ("shaped like an almond") and located deep in the brain, near the inner surface of each temporal lobe.

Angular gyrus. An area of the cortex in the parietal lobe involved in processing the sound structure of language and in reading.

Anhedonia. Recognised as one of the key symptoms of the mood disorder depression. Patients with anhedonia are unable to experience pleasure from normally pleasurable life events such as eating, exercise, and social/sexual interactions.

Anterior cingulated cortex. Frontal part of the cingulate cortex. It plays a role in a wide variety of autonomic functions, such as regulating heart rate and blood pressure, and is vital to cognitive functions, such as reward anticipation, decision-making, empathy, and emotions.

Aphasia. Disturbance in language comprehension or production.

Apolipoprotein E (or "apoE"). Has been studied for many years for its involvement in cardiovascular diseases. It has only recently been found that one allele (gene factor) of the aopE gene (E4) is a risk factor for Alzheimer's disease.

Artificial intelligence (AI). A field of computer science which attempts to develop machines that behave "intelligently".

Attention. Attention is the cognitive process of selectively concentrating on one task while ignoring other tasks. Imaging studies have been able to show the distinct networks of neural areas which carry out the various functions of attention such as maintaining the alert state, orienting to sensory information and resolving conflict among competing thoughts or feelings.

Auditory cortex. The region of the brain that is responsible for processing of auditory (sound) information.

Auditory nerve. A bundle of nerve fibers extending from the cochlea of the ear to the brain, which contains two branches: the cochlear nerve that transmits sound information and the vestibular nerve that relays information related to balance.

Autism/autistic spectrum disorders. A spectrum of neurodevelopmental conditions, characterised by difficulties in the development of social relationships, communication skills, repetitive behaviour, and learning difficulties.

Axon. The fiberlike extension of a neuron by which the cell sends information to target cells.

Basal ganglia. Clusters of neurons, which include the caudate nucleus, putamen, globus pallidus and substantia nigra, that are located deep in the brain and play an important role in movement. Cell death in the substantia nigra contributes to Parkinsonian signs.

Bipolar disorder. Otherwise known as manic depression. Bipolar disorder involves extreme swings of mood from mania (a form of euphoria) to deep depression. There is no simple cause, although there is strong evidence that it is associated with internal chemical changes to various natural transmitters of mood to the brain, but the precise way in which this happens is not yet known. The disorder can be triggered by the stresses and strains of everyday life, or a traumatic event or, in rare cases, physical trauma such as a head injury.

Brainstem. The major route by which the forebrain sends information to and receives information from the spinal cord and peripheral nerves. It controls, among other things, respiration and regulation of heart rhythms.

Broca's area. The brain region located in the frontal lobe of the left hemisphere, involved in the production of speech.

Caudate or caudale nucleus. A telencephalic nucleus located within the basal ganglia in the brain. The caudate is an important part of the brain's learning and memory system.

Cerebellum. A part of the brain located at the back and below the principal hemispheres, involved in the regulation of movement.

Cerebral hemispheres. The two specialised halves of the brain. The left hemisphere is specialised for speech, writing, language and calculation; the right hemisphere is specialised for spatial abilities, face recognition in vision and some aspects of music perception and production.

Cerebrospinal fluid. A liquid found within the ventricles of the brain and the central canal of the spinal cord.

Cerebrum. Otherwise known by more technical term telencephalon. Refers to cerebral hemispheres and other, smaller structures within the brain, and is composed of the following sub-regions: limbic system, cerebral cortex, basal ganglia, and olfactory bulb.

Circadian clock/rhythm. A cycle of behavior or physiological change lasting approximately 24 hours.

Classical conditioning. Learning in which a stimulus that naturally produces a specific response (unconditioned stimulus) is repeatedly paired with a neutral stimulus (conditioned stimulus). As a result, the conditioned stimulus can become able to evoke a response similar to that of the unconditioned stimulus.

Cochlea. A snail-shaped, fluid-filled organ of the inner ear responsible for transducing motion into neurotransmission to produce an auditory sensation.

Cognition. Set of operations of the mind which includes all aspects of perceiving, thinking, learning, and remembering.

Cognitive maps. Mental representations of objects and places as located in the environment.

Cognitive networks. Networks in the brain involved in processes such as memory, attention, perception, action, problem solving and mental imagery. This term is also used for artificial networks as in artificial intelligence.

Cognitive neuroscience. Study and development of mind and brain research aimed at investigating the psychological, computational, and neuroscientific bases of cognition.

Cognitive science. Study of the mind. An interdisciplinary science that draws upon many fields including neuroscience, psychology, philosophy, computer science, artificial intelligence, and linguistics. The purpose of cognitive science is to develop models that help explain human cognition – perception, thinking, and learning.

Cognitive training. Teaching methods and training to remediate cognitive deficits.

Cohort study. A type of longitudinal study used in medicine and social sciences that compares a cohort, or group of people who share a common characteristic or experience, to an outside group.

Competences. Referring to student ability. The mental capacity to perform particular tasks.

Constructivism. A learning theory whereby individuals actively construct understanding from their experiences.

Corpus callosum. The large bundle of nerve fibers linking the left and right cerebral hemispheres.

(cerebral) Cortex. Outer layer of the brain.

Cortisol. A hormone manufactured by the adrenal cortex. In humans, it is secreted in greatest quantities before dawn, readying the body for the activities of the coming day.

Critical period. Concept referring to certain periods when the brain's capacity for adjustment in response to experience is substantially greater than during other periods. In humans, critical periods only exist during prenatal development. Sensitive periods, however, are known to occur in childhood (see sensitive period).

Cross-sectional study. A type of descriptive study that measures the frequency and characteristics of a population at a particular point in time.

CT (Computed Tomography). Originally known as computed axial tomography (CAT or CT scan) and body section roentgenography. A medical imaging method employing tomography where digital geometry processing is used to generate a three-dimensional image of the internals of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation.

Decoding. An elementary process in learning to read alphabetic writing systems (for example, English, Spanish, German or Italian) in which unfamiliar words are deciphered by associating the letters of words with corresponding speech sounds.

(senile) Dementia. A condition of deteriorated mentality that is characterised by marked decline from the individual's former intellectual level and often by emotional apathy. Alzheimer's disease is one form of dementia.

Dendrite. A tree-like extension of the neuron cell body. It receives information from other neurons.

Depression. A lowering of vitality of functional activity: the state of being below normal in physical or mental vitality. Senile depression refers to depression in later life which may be dominated by agitation and hypochondria. Whether this form of depression is distinct from depression during earlier life is not clear.

Development. Progressive change that occurs in human beings as they age. Biological inclinations interact with experience to guide development throughout life.

DNA (Deoxyribonucleic acid). DNA is a long polymer of nucleotides (a polynucleotide) that encodes the sequence of amino acid residues in proteins, using the genetic code.

Dopamine. A catecholamine neurotransmitter known to have multiple functions depending on where it acts. Dopamine-containing neurons in the substantia nigra of the brainstem project to the caudate nucleus and are destroyed in Parkinson's victims. Dopamine is thought to regulate emotional responses, and play a role in schizophrenia and cocaine abuse.

DTI (Diffusion Tensor Imaging). A magnetic resonance imaging (MRI) technique that enables the measurement of the restricted diffusion of water in tissue. It allows the observation of molecular diffusion in tissues in vivo and therefore the molecular organisation in tissues.

Dyscalculia. Impairment of the ability to perform simple arithmetical computations, despite conventional instruction, adequate intelligence and socio-cultural opportunity.

Dyslexia. A disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and socio-cultural opportunity.

Dyspraxia. Motor co-ordination difficulties in carrying out any complex sequence.

ECG (Electrocardiogram). A recording of the electrical voltage in the heart in the form of a continuous strip graph.

EEG (Electroencephalogram). A measurement of the brain's electrical activity via electrodes. EEG is derived from sensors placed in various spots on the scalp, which are sensitive to the summed activity of populations of neurons in a particular region of the brain.

Electrochemical signals. These signals are the means by which neurons communicate with one another.

Emotional intelligence. Sometimes referred to as emotional quotient ("EQ"). Individuals with emotional intelligence are able to relate to others with compassion and empathy, have well-developed social skills, and use this emotional awareness to direct their actions and behaviour. The term was coined in 1990.

Emotional regulation. Ability to regulate and appropriately temper emotions.

Emotions. There is no single universally accepted definition. The neurobiological explanation of human emotion is that emotion is a pleasant or unpleasant mental state organised mostly in the limbic system of the mammalian brain.

Endocrine organ. An organ that secretes a hormone directly into the bloodstream to regulate cellular activity of certain other organs.

Endorphins. Neurotransmitters produced in the brain that generate cellular and behavioral effects similar to those of morphine.

Epigenetic. Changes in gene function, often elicited by environmental factors.

Epilepsy. A chronic nervous disorder in humans which produces convulsions of greater or lesser severity with clouding of consciousness; it involves changes in the state of consciousness and of motion due to either an inborn defect of a lesion of the brain produced by tumour, injury, toxic agents, or glandular disturbances.

ERP (Event-related potentials). Electric signals are first recorded with an EEG. Data from this technology is then time locked to the repeated presentation of a stimulus to the subject, in order to see the brain in action. The resulting brain activation (or event-related potentials) can then be related to the stimulus event.

Evoked potentials. A measure of the brain's electrical activity in response to sensory stimuli. This is obtained by placing electrodes on the surface of the scalp (or more rarely, inside the head), repeatedly administering a stimulus, and then using a computer to average the results.

Excitation. A change in the electrical state of a neuron that is associated with an enhanced probability of action potentials.

Excitatory synapses. Synapses where neurotransmitters decrease the potential difference across neuron membranes.

Experience-dependent. A property of a functional neural system in which variations in experience lead to variations in function, a property that might persist throughout the life-span.

Experience-expectant. A property of a functional neural system in which the development of the system has evolved to critically depend on stable environmental inputs that are roughly the same for all members of species (*i.e.* stimulation of both eyes in newborns during development of ocular dominance columns). This property is thought to operate early in life.

Explicit memory. Memories that can be retrieved by a conscious act, as in recall, and can be verbalised, in contrast to implicit or procedural memories, which are less verbally explicit.

Fatty acids. The human body can produce all but two (linoleic acid and alpha-linolenic acid) of the fatty acids it needs which the brain is made up of. Since they cannot be made in the body from other substrates and must be supplied in food (namely in plant and fish oils) they are called essential fatty acids. (See also Omega and HUFA).

Fear/fear conditioning. Fear conditioning is a form of classical conditioning (a type of associative learning pioneered on animals by Ivan Pavlov in the 1920s) involving the repeated pairing of a harmless stimulus such as a light, called the conditioned stimulus, with a noxious stimulus such as a mild shock, called the unconditioned stimulus, until the animal shows a fear response not just to the shock but to the light alone, called a conditioned response. Fear conditioning is thought to depend upon the amygdala. Blocking the amygdala can prevent the expression of fear.

fMRI (Functional Magnetic Resonance Imaging). Use of an MRI scanner to view neural activity indirectly through changes in blood chemistry (such as the level of oxygen) and investigate increases in activity within brain areas that are associated with various forms of stimuli and mental tasks (see MRI).

Forebrain. The largest division of the brain, which includes the cerebral cortex and basal ganglia. It is credited with the highest intellectual functions.

Frontal lobe. One of the four divisions (parietal, temporal, occipital) of each hemisphere of the cerebral cortex. It has a role in controlling movement and associating the functions of other cortical areas, believed to be involved in planning and higher order thinking.

Functional imaging. Represents a range of measurement techniques in which the aim is to extract quantitative information about physiological function.

Fusiform gyrus. A cortical region running along the ventral (bottom) surface of the occipital-temporal lobes associated with visual processes. Functional activity suggests that this area is specialised for visual face processing and visual word forms.

Gene. A gene is the unit of heredity in living organisms. Genes influence the physical development and behaviour of the organism. See also genetics.

Genetics. The science of genes, heredity, and the variation of organisms. **Classical genetics** consists of the techniques and methodologies of genetics predating molecular biology. **Molecular genetics** builds upon the foundation of classical genetics but focuses on the structure and function of genes at a molecular level. **Behavioral genetics** studies the influence of varying genetics on animal behaviour, and the causes and effects of human disorders.

Glia/glial cells. Specialised cells that nourish and support neurons.

Graphemes. The smallest unit of written language, including letters, Chinese characters, numerals, and punctuation marks.

Grey matter/gray matter. Gray matter consists of neurons' cell bodies and dendrites.

Gyrus/gyri. The circular convolutions of the cortex of which each has been given an identifying name: middle frontal gyrus, superior frontal gyrus, inferior frontal gyrus, left interior frontal gyrus, posterior middle gyrus, postcentral gyrus, supermaginal gyrus, angular gyrus, left angular gyrus, left fusiform gyrus, cingulated gyrus.

Hard-wired. Meaning "not changeable". In contrast to concept of plasticity in which brain is malleable to change.

(cerebral) Hemisphere. One of two sides of the brain classified as "left" and "right".

Hippocampus. A seahorse-shaped structure located within the brain and considered an important part of the limbic system. It functions in learning, memory and emotions.

Hormones. Chemical messengers secreted by endocrine glands to regulate the activity of target cells. They play a role in sexual development, calcium and bone metabolism, growth and many other activities.

HUFA (Highly unsaturated fatty acids).

Hypothalamus. A complex brain structure composed of many nuclei with various functions. These include regulating the activities of internal organs, monitoring information from the autonomic nervous system and controlling the pituitary gland.

Immune system. The combination of cells, organs and tissues which work together to protect the body from infection.

Implicit memory/learning. Memories that cannot be retrieved consciously but are activated as part of particular skills or action, and reflect learning a procedure of a pattern, which might be difficult to explicitly verbalise or consciously reflect upon (*i.e.* memory that allows you to engage in a procedure faster the second time, such as tying a shoe).

Information-processing. An analysis of human cognition into a set of steps whereby abstract information is processed.

Inhibition. In reference to neurons, this is a synaptic message that prevents the recipient cell from firing.

Insomnia. Inability to remain asleep for a reasonable period.

Intelligence. Characeristic of the mind lacking a scientific definition. Can be fluid or crystallised intelligence (see also multiple intelligences, IQ).

Interference theory. A theory of forgetting in which other memories interfere with the retention of the target memory.

Ions. Electrically charged atoms.

IQ. A number held to express the relative intelligence of a person originally determined by dividing mental by chronological age and multiplying by 100.

Left-brained thinking. A lay term based on the misconception that higher level thought processes are strictly divided into roles that occur independently in different halves of the brain. Thought to be based on exaggerations of specific findings of left hemisphere speclialisations, such as the neural systems that control speaking.

Limbic system. Also known as the "emotional brain". It borders the thalamus and hyphothalamus and is made up of many of the deep brain structures – including the amygdala, hippocampus, septum and basal ganglia – that work to help regulate emotion, memory and certain aspects of movement.

Lobe. Gross areas of the brain sectioned by function (see also occipital, temporal, parietal and frontal).

Long-term memory. The final phase of memory in which information storage may last from hours to a lifetime.

Longitudinal study. Studies that track the development of individuals over an extended period of time.

Long-term potentiation (LTP). The increase in neuron responsiveness as a function of past stimulation.

MEG (Magnetoencephalography). A non-invasive functional brain imaging technique sensitive to rapid changes in brain activity. Recording devices ("SQUIDs" for *Superconducting Quantum Interference Devices*) placed near the head are sensitive to small magnetic fluctuations associated with neural activity in the cortex. Responses to events can be traced out on a millisecond time scale with good spatial resolution for those generators to which the technique is sensitive.

Melatonin. Produced from serotonin, melatonin is released by the pineal gland into the bloodstream. It affects physiological changes related to time and lighting cycles.

Memory. Working memory/or short-term memory refers to structures and processes used for temporarily storing and manipulating information. **Long-term memory** stores memory as meaning. Short-term memory can become long-term memory through the process of rehearsal and meaningful association.

Memory consolidation. The physical and psychological changes that take place as the brain organises and restructures information in order to make it a part of memory.

Memory span. The amount of information that can be perfectly remembered in an immediate test of memory.

Mental imagery. Also known as visualisation. Mental images are created by the brain from memories, imagination, or a combination of both. It is hypothesised that brain areas responsible for perception are also implicated during mental imagery.

Mental images. Internal representations consisting of visual and spatial information.

Metabolism. The sum of all physical and chemical changes that take place within an organism and all energy transformations that occur within living cells.

Meta-cognition. Conscious awareness of one's own cognitive and learning processes. In short, "thinking about thinking".

Micro-array. A tool for analysing gene expression that consists of a glass slide or other solid support with the sequences of many different genes attached at fixed locations. By using an array containing many DNA samples, scientists can determine the expression levels of hundreds or thousands of genes within a cell in a single experiment.

Micro-genetics. A method of tracking change during development. The micro–genetic method stresses that change is continual and occurs at many different points aside from the major stage changes. Tracking these ongoing changes can help researchers understand how children learn.

Mind. The mind is what the brain does, it includes intellect and consciousness.

Mirror neurons. A neuron which fires both when a human performs an action and when a human observes the same action performed by another. Mirror neurons therefore "mirror" behaviours as if the observer himself was performing the action.

Mnemonic technique. A technique which enhances memory performance.

Morphology. In linguistics, morphology is the study of word structure.

Motivation. Can be defined as whatever causes to act. Motivation reflects states in which the organism is prepared to act physically and mentally in a focussed manner, that is, in states characterised by raised levels of arousal. Accordingly, motivation is intimately related to emotions as emotions constitute the brain's way of evaluating whether things should be acted upon. **Intrinsic motivation** is evident when people engage in an activity for its own sake, without some obvious external incentive present, as opposed to **external/ extrinsic motivation** which is reward-driven.

Motor cortex. Regions of the cerebral cortex involved in the planning, control, and execution of voluntary motor functions.

Motor neuron. A neuron that carries information from the central nervous system to the muscle.

MRI (Magnetic Resonance Imaging). A non-invasive technique used to create images of the structures within a living human brain, through the combination of a strong magnetic field and radio frequency impulses.

Multiple intelligences. Theory that each individual has multiple, partially distinct, intelligences, including: linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, and intrapersonal.

Multiple sclerosis/MS. A chronic, inflammatory disease affecting the central nervous system.

Multi-tasking. Simultaneous performance of two or more tasks.

Myelin/myelination. Compact fatty material that surrounds and insulates axons of some neurons. Process by which nerves are covered by a protective fatty substance. The sheath (myelin) around the nerve fibres acts electrically as a conduit in an electrical system, increasing the speed at which messages can be sent.

Myth of three. Also known as the "Myth of the Early Years". This assumption states that only the first three years really matter in altering brain activity and after that the brain is insensitive to change. This extreme "critical period" viewpoint is not accurate. In fact, the brain is responsive to change throughout the lifespan.

Neurobiology. The study of cells and systems of the nervous system.

Neurodegenerative diseases. Disorders of the brain and nervous system leading to brain dysfunction and degeneration including Alzheimer's diseases, Parkinson's disease and other neurodegenerative disorders that frequently occur with advancing age.

Neurogenesis. The birth of new neurons.

Neuromyth. Misconception generated by a misunderstanding, a misreading or misquoting of facts scientifically established (by brain research) to make a case for use of brain research, in education and other contexts.

Neuron. Nerve cell. It is specialised for the transmission of information and characterised by long fibrous projections called axons, and shorter, branch-like projections called dendrites. Basic building block of the nervous system; specialised cell for integration and transmission of information.

Neurotransmitter. A chemical released by neurons at a synapse for the purpose of relaying information via receptors.

NIRS (Near Infrared Spectroscopy). Non-invasive imaging method which allows measures of the concentrations of deoxygenated haemoglobin in the brain by near-infrared absorption (near-infrared light at a wavelength between 700 nm and 900 nm can partially penetrate through human tissues).

Nucleus accumbens. The nucleus accumbens (also known as the accumbens nucleus or nucleus accumbens septi) is a collection of neurons located where the head of the caudate and the anterior portion of the putamen meet just lateral to the septum pellucidum. The nucleus accumbens, the ventral olfactory tubercle, and ventral caudate and putamen collectively form the ventral striatum. This nucleus is thought to play an important role in reward, pleasure, and addiction.

Nurture. The process of caring for and teaching a child as the child grows.

Occipital lobe. Posterior region of the cerebral cortex receiving visual information.

Occipito-temporal cortex. Also known as Brodman's area is part of the temporal cortex in the human brain.

Omega fatty acids. Polyunsaturated fatty acids which cannot be synthesised in the body.

Ontogenesis. The developmental history of an individual.

Orthography. The set of rules about how to write correctly in the writing system of a language.

OT (Optical Topography). Non-invasive trans-cranial imaging method for higher-order brain functions. This method, based on near-infrared spectroscopy, is robust to motion, so that a subject can be tested under natural conditions.

Oxytocin. Also known as the "love hormone". Oxytocin is involved in social recognition and bonding, and might be involved in the formation of trust between people.

Pallidum/globus pallidus. A sub-cortical structure of the brain.

Parasympathetic nervous system. A branch of the autonomic nervous system concerned with the conservation of the body's energy and resources during relaxed states.

Parietal lobe. One of the four subdivisions of the cerebral cortex. It plays a role in sensory processes, attention and language. Involved in many functions such as processing spatial information, body image, orienting to locations, etc. Can be subdivided into superior parietal lobule and inferior parietal lobule. The precuneus, postcentral gyrus, supramaginal gyrus and angular gyrus make up the parietal lobe.

Parkinson's disease. A degenerative disorder of the central nervous system that affects the control of muscles, and so may affect movement, speech and posture (see also neurodegenarative disorders).

Peripheral nervous system. A division of the nervous system consisting of all nerves which are not part of the brain or spinal cord.

Perisylvian areas. Cortical regions that are adjacent to the sylvian fissure – major fissure on the lateral surface of the brain running along the temporal lobe.

PET (Positron Emission Tomography). A variety of techniques that use positron emitting radionucleides to create an image of brain activity; often blood flow or metabolic activity. PET produces three-dimensional, coloured images of chemicals or substances functioning within the brain.

Phonemes. Basic units of oral speech that make up words.

Phylogenic development. The process of evolution which favors those genetic behavioural traits in both genders that best assure survival of the species.

Pineal gland. An endocrine organ found in the brain. In some animals, it seems to serve as a light-influenced biological clock.

Pituitary gland. An endocrine organ closely linked with the hypothalamus. In humans, it is composed of two lobes and secretes a number of hormones that regulate the activity of other endocrine organs in the body.

Plasticity. Also "brain plasticity". The phenomenon of how the brain changes and learns in response to experience. See also experience-expectant/experience-dependent plasticity.

Precuneus. Structure in the brain positioned above the cuneus and located in the parietal lobe.

Prefrontal cortex. The region in front of the frontal cortex which is involved in planning and other higher-level cognition.

Primary motor cortex. Works in association with pre-motor areas to plan and execute movements.

Primary visual cortex. The region of the occipital cortex where most visual information first arrives.

Pruning/synaptic pruning. The natural process of eliminating weak synaptic contacts.

Putamen. A component of the limbic system. This part is responsible for familiar motor skills.

Qualia. A term for subjective sensations. In "Phantoms In The Brain", Professor Ramachandran describes the riddle of qualia like this. How can the flux of ions and electrical currents in little specks of jelly, which are the neurons in my brain, generate the whole subjective world of sensations like red, warmth, cold or pain? By what magic is matter transmuted into the invisible fabric of feelings and sensations?

Reasoning. The act of using reason to derive a conclusion from certain premises using a given methodology. Two most commonly used explicit methods to reach a conclusion are **deductive reasoning** in which the conclusion derived from previously known facts, and **inductive reasoning**, in which the premises of an argument are believed to support the conclusion but do not ensure it.

REM (Rapid eye movement sleep). The stage of sleep characterised by rapid movements of the eyes, when the activity of the brain's neurons is quite similar to that during waking hours.

"**Reptilian" brain (so-called).** Refers to the brain stem which is the oldest region in the evolving human brain.

Right-brained thinking. A lay term based on the misconception that higher level thought processes are strictly divided into roles that occur independently in different halves of the brain. Thought to be based in exaggerations of specific findings of right hemisphere specialisation in some limited domains.

Schizophrenia. A mental disorder characterised by impairments in the perception or expression of reality and/or by significant social or occupational dysfunction.

Science of learning. Term that attempts to provide a label for the type of research possible when cognitive neuroscience and other relevant disciplines research joins with educational research and practice.

Second messengers. Recently recognised substances that trigger communications between different parts of a neuron. These chemicals are thought to play a role in the manufacture and release of neurotransmitters, intracellular movements, carbohydrate metabolism and, possibly, even processes of growth and development. Their direct effects on the genetic material of cells may lead to long-term alterations of behavior, such as memory.

Sensitive period. Time frame in which a particular biological event is likely to occur best. Scientists have documented sensitive periods for certain types of sensory stimuli (such as vision and speech sounds), and for certain emotional and cognitive experiences (such as attachment and language exposure). However, there are many mental skills, such as reading, vocabulary size, and the ability to see colour, which to do not appear to pass through tight sensitive periods in the development.

Serotonin. A monoamine neurotransmitter believed to play many roles including, but not limited to, temperature regulation, sensory perception and the onset of sleep. Neurons using serotonin as a transmitter are found in the brain and in the gut. A number of antidepressant drugs are targeted to brain serotonin systems.

Short-term memory. A phase of memory in which a limited amount of information may be held for several seconds to minutes.

SPECT. Functional imaging using single photon emission computerised tomography.

Stimulus. An environmental event capable of being detected by sensory receptors.

Stress. The physical and mental responses to anything that causes a real or imagined experiences and changes in life. Persistent and/or excessive stress may lead to depressive (withdrawal) behaviour.

Striatum. A subcortical part of the telencephalon, best known for its role in the planning and modulation of movement pathways but is also involved in a variety of other cognitive processes involving executive function.

Stroop task. A psychological test for mental vitality and flexibility. *E.g.* If a word is printed or displayed in a color different from the color it actually names; for example, if the word "green" is written in blue ink , a delay occurs in the processing of the word's color, leading to slower test reaction times and an increase in mistakes.

Sulcus/sulci. A furrow of convuluted brain surface. While gyri protrude from the surface, sulci recede, forming valleys between gyri.

Sympathetic nervous system. A branch of the autonomic nervous system responsible for mobilising the body's energy and resources during times of stress and arousal.

Synapse. A gap between two neurons that functions as the site of information transfer from one neuron to another (called "target cell" or "postsynaptic neuron").

Synaptic density. Refers to the number of synapses associated with one neuron. More synapses per neuron are thought to indicate a richer ability of representation and adaption.

Synaptic pruning. Process in brain development whereby unused synapses (connections among neurons) are shed. Experience determines which synapses will be shed and which will be preserved.

Synaptogenesis. Formation of a synapse.

Temporal lobe. One of the four major subdivisions of each hemisphere of the cerebral cortex. It functions in auditory perception, speech and complex visual perceptions.

Terminal/Axon terminal. A specialised structure at the end of the axon that is used to release neurotransmitter chemicals and communicate with target neurons.

Thalamus. A structure consisting of two egg-shaped masses of nerve tissue, each about the size of a walnut, deep within the brain. It is the key relay station for sensory information flowing into the brain, filtering out only information of particular importance from the mass of signals entering the brain.

TMS (Transcranial magnetic stimulation). A procedure in which electrical activity in the brain is influenced by a pulsed magnetic field. Recently, TMS has been used to investigate aspects of cortical processing, including sensory and cognitive functions.

Trans-disciplinarity. Term used to explain the concept of fusing completely different disciplines resulting in a new discipline with its own conceptual structure, known to extend the borders of the original sciences and disciplines included in its formation.

Ventricles. Of the four ventricles, comparatively large spaces filled with cerebrospinal fluid, three are located in the brain and one in the brainstem. The lateral ventricles, the two largest, are symmetrically placed above the brainstem, one in each hemisphere.

Visual cortex. Located in the occipital lobe; involved in detection of visual stimuli.

Wernicke's area. A brain region involved in the comprehension of language and the production of meaningful speech.

White matter. White matter consists of myelinated axons that connect various grey matter areas of the brain.

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