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# **Knowledge of Brain Development and Mental functioning opens up a fresh perspective on therapeutic interventions in psychotherapy**

## **Abstract**

This paper provides an overview of the rapidly expanding body of knowledge on brain development and mental functioning now available in the second decade of the 21<sup>st</sup> century. This knowledge has grown from significant new and related discoveries in genetics, in molecular biology, and in brain imaging over the past 15 years and now creates the possibility of taking forward Freud's Project for a Scientific Psychology which he put to one side in 1895. I use ordinary everyday language to describe very complex issues in brain development and in mental functioning. I present relevant information on brain anatomy and physiology, discuss the significance of periods of rapid brain growth and development, and highlight regulatory systems and the connections of the processes of memory with learning, emotions and attachment. I suggest ways in which this knowledge may be of particular interest to the practice of psychotherapy.

**Key words:** brain development, epigenetic, molecular biology, neuro- imaging, psychotherapy.

## **Sigmund Freud, brain imaging, human genetics and molecular biology**

Freud practiced as a neurologist in Vienna while developing his interest in understanding all aspects of mental functioning more fully (Freud E, Freud L and Grubrich-Simitis, 1985). He wanted to be able to integrate his knowledge of brain functioning with his evolving interest in mental phenomena and with the new evolving science of psychoanalysis (Ellenberger H F, 1970). Freud (1895) wrote the “Project for a Scientific Psychology” as an attempt to integrate his understanding of the brain and the mind. Unfortunately the available knowledge of the brain and the means to explore this further at the end of the 19<sup>th</sup> Century were not adequate for this task. Freud therefore resolved to concentrate his efforts on understanding mental functioning more fully and left it for posterity to attempt to integrate this understanding with a fuller understanding of brain development when the time, and the means of investigation, was right.

For many years, scientists seeking to understand the structure and function of the various parts of the human brain had only indirect methods of doing so. They were able to make certain inferences about the functional roles of particular brain structures by performing post mortem dissections on the brains of healthy individuals and of individuals who had displayed specific functional deficits caused by localized brain lesions. Selectively destroying certain parts of the brain in animal subjects was another investigative method that confirmed the role of certain brain structures. Around the mid-20th century, researchers such as Wilder Penfield developed the first functional maps of the human brain by applying electrical stimuli to it directly during surgical operations (Penfield W, 1950).

Since the early 1990s, however, a variety of imaging technologies have revolutionized brain research. These technologies let scientists see what is happening inside subjects’ brains

without having to open up their skulls. Now researchers can ask subjects to perform specific mental tasks, then “watch their brains think” as they perform these tasks in real time. These imaging technologies were made possible largely by the progress achieved in computer science and in the detection of various forms of radiation toward the end of the 20th century.

Brain imaging is generally divided into two categories: structural imaging and functional imaging. The purpose of structural imaging is to visualize the various structures of the brain and any physical abnormalities that may affect them. The purpose of functional imaging is to measure activity in certain parts of the brain while it performs certain tasks. Functional imaging is used chiefly in research, to improve our understanding of the various structures of the human brain. Computerised Axial Tomography (CAT), Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI) and functional MRI (fMRI) are all now readily available in large centres and are used increasingly in research into brain functioning (Folensbee R W, 2007). Each scanner costs up to £2.5 million to install and up to £500,000 per year to run.

There have been major advances also in our knowledge of genetics since the discovery of the double helical structure of deoxyribonucleic acid (DNA) by Watson and Crick in 1953. Each strand in this double helix is made up of four small repeating units called nucleotide bases – adenine, thymine, guanine and cytosine. Adenine in one strand pairs with and binds always to thymine in the other, and guanine always to cytosine thus holding the strands together. Molecular biology is a hybrid discipline of genetics and biochemistry that attempts to understand life processes at the level of the macromolecules of the cell and at the level of their structure and function.

Our genes are seen to have two functions. ‘The template function’ allows our genes to replicate and make copies that are passed from generation to generation. ‘The transcription

function' refers to a gene being turned on to make a new protein that alters the structure and function of the cell. This transcription function is influenced by what we do or think. Information inherited through encoding on DNA can be activated or suppressed by other genetic or environmental elements. Information is also remembered through the actions of messenger ribonucleic acid (mRNA) but is not transmitted genetically to other generations in this way. Like DNA messenger RNA is a nucleic acid made up of four nucleotides – adenine, guanine, cytosine and uracil (unique to RNA). The sequence of nucleotides in messenger RNA is translated into protein. Watson and Crick thus formulated the central dogma of molecular biology: DNA makes RNA, and RNA makes protein (Kandel E R, 2006).

The practical applications of this knowledge to our clinical work are varied. Kandel argues that when psychotherapy changes people it does so through learning. It produces changes in gene expression that alter the strength of synaptic connections. Structural changes that alter the anatomical pattern of interconnections between cells of the brain are also responsible for the changes resulting from psychotherapy (Kandel E R, 1998). In an exciting link to attachment theory, polymorphism in the serotonin transporter gene (5-HTTLPR) has been typed and is seen to be clinically relevant. Attachment patterns in infants were explored on the basis of the genetic expression of the serotonin transporter gene. For short allele (ss/sl) infants, low responsiveness in mother predicted particularly high risk for insecure attachment, and high responsiveness offset that risk. For infants homozygous for the long allele (ll) there was no association between responsiveness and attachment organization. Homozygous infants were securely attached whatever the responsiveness of the mother (Robin A B, Kochanska G, Philibert R A, 2008).

The complexity of the molecular biology of the neuron is illustrated by an exploration of the intricacies of chemical transmission of impulses across synaptic gaps between neurons and by the impact of the chemical involved on the biochemistry of the post synaptic neuron. There are nine different types of classical neurotransmitters – glutamate, glycin, gaba-amino-butyric acid (GABA), dopamine, noradrenaline, adrenaline, serotonin, histamine and acetylcholine – and more than 50 types of neuroactive peptides. Most neurons produce multiple neurotransmitters which act on very different timescales. The effects of glutamate and GABA transpire within milliseconds, those of dopamine and serotonin within seconds or minutes, and those of the neuropeptides and neurohormones often within hours, days, or even weeks (Grawe K, 2007). Activating AMPA (alpha-amino-3hydroxy-5-methylisoxazole-4-propionic acid) receptors and inhibiting GABA receptors are primarily involved in the process of rapid signal propagation. NMDA (N-methyl-d-aspartate) receptors react more slowly and require the prior activation of the postsynaptic neuron to allow calcium to flow into the cell. Calcium then activates a second messenger in the cell which triggers a chemical cascade that strengthens the transmission properties of the synapses. This is known as long term potentiation of the synapses.

An increase in the second messenger cAMP (cyclical adenosine monophosphate) then activates protein kinase A (PKA). This in turn activates a protein called CREB (cAmp-responsive-element-binding-protein), and activates genes within the cell nucleus to start producing new proteins. These proteins facilitate excitability of previously activated synapses and enhance the production of neurotrophines that lead to the formation of additional synapses around previously activated synapses. They increase the production of so-called retrograde messengers thus ensuring more neurotransmitters are being produced at the presynaptic cell. Life at intracellular and intercellular levels is indeed complex.

Freud would probably be very happy to be alive in our age of advancing knowledge of brain development and mental functioning. Many of his fellow psychoanalytic practitioners are developing a similar interest in understanding the brain as a way of appreciating the complexities of mental functioning. Some of us are frightened off by the thought of exploring the complexities of the brain, some by the opaque language used to describe its anatomical parts, and perhaps some of us by the fear of being shown to be stupid in not understanding what is increasingly being seen by many as a fresh way of grasping human development and interactions. I write this article for all of us working as psychotherapists who wish to continue to be curious about human brain development. In particular I am writing for colleagues like myself whose curiosity can be temporarily stunted by the complexity and size of the task before us.

## **The Brain**

### **The Triune Brain and remembering some microanatomy and physiology**

Paul Mc Lean (1990) developed the concept of the triune brain over the past 50 years. According to his theory, the following three distinct brains emerged successively in the course of evolution and now co-inhabit the human skull: The reflex or reptilian brain is the oldest of the three and consists of the structures of the brainstem and the cerebellum. It controls the body's vital functions such as heart rate, breathing, body temperature and balance. The reptilian brain is reliable but tends to be somewhat rigid and compulsive in function. The feeling or limbic brain emerged in the first mammals and consists of areas of brain cells and their connections known as the hippocampus, the amygdala, and the hypothalamus. It records memories of behaviours that produce agreeable and disagreeable experiences. It is responsible for what are called emotions in human beings. The limbic brain is the seat of the value judgments that we make, often unconsciously, that can exert

such a strong influence on our behaviour. The thinking brain or the neocortex first assumed importance in primates. It culminated in the human brain with its two dominant large ‘cerebral hemispheres’. These hemispheres have been responsible for the development of human language, abstract thought, imagination, and consciousness. The neocortex is flexible and has almost infinite learning abilities. Learning is a process that will modify a subsequent behaviour. Memory is basically nothing more than the record left by a learning process. The neocortex is what has enabled human cultures to develop.

These three parts of the brain do not operate independently of one another. They have established numerous interconnections through which they influence one another. The neural pathways from the limbic system to the cortex, for example, are especially well developed.

### **Image 1: The Anatomy of the Triune Human Brain**

In the 1960s Social Psychiatrists were very likely to use the phrase “I am my own experiences” when conveying their sense of what mental development was all about. They were not aware at the time of the future explosion of information on the functioning of the brain that would confirm this statement as so accurate in describing the development of the brain itself.

Experiences arriving at areas of our brains through our senses are laid down as ‘memories’ in specific areas of the brain, and integrated through neural connections across a number of functional systems in our brains. We gain sensory experiences through our senses of vision, hearing, touch, taste and smell. Each motor experience is likewise registered in specific parts of the brain and integrated across a number of brain areas and functional systems necessary for the finer control of movement and actions. An infant learns to control head movements, turn over, sit up, crawl, walk, run, control hand movements, develop precise hand

coordination, vocalise, make words, link words, make sentences, and make verbal sense all in the first 3 years of life. All such progress is registered in neural networks of the brain.

**Image 2: The representation of the body in specific areas of the brain**

In the diagram above (from 'The brain from top to bottom', 2009) a cross-section of the brain illustrates how the different anatomical areas of the body are represented on the primary motor cortex area of the frontal lobes of the brain. The body, as it were, hangs over the large gap or fissure between both sides of the brain with the main body and legs falling down into the fissure or gap, and with large areas of the outer surface of the frontal cortex being devoted to registering and controlling movements in parts of our bodies such as our hands and our faces that are complex and varied in their movements and actions.

The blueprint for brain development is genetically mediated. Genetics determines the form and structure of our brains, especially what we understand as our reptilian brain. Our limbic brain is likewise to a great extent genetically determined but it is also directly influenced by experiences we have as infants. Such experiences are laid down in neural networks within the limbic structures, and in the neural networks that connect to the limbic structures. The timing of patterns of brain growth and development is genetically determined but it is also influenced by experiences and by environmental factors.

The building blocks of the brain are neurons, nerve cells that each makes thousands of connections with other nerve cells. Chemicals known as neurotransmitters make connections across the gaps between cells, known as synapses. Small electrical impulses are transmitted quickly down long fibre-like outgrowths, known as axons, from the body of the nerve cell, which connect with thousands of other neurons. These mechanisms of neuron development and action are genetically laid down in DNA, the genetic material of the neurons. Neurons

are supported in turn by other cells in the brain, which ensure the presence of the correct environment and the correct nourishment for neural growth and activity. Some of these supporting cells coat the axon of the neuron with a protective covering that quickens the transmission of nerve impulses down the axon. This process is known as myelination and makes for more effective and more efficient nerve impulse transmission.

### **Image 3: The neuron is the building block of the brain**

The capacity of neurons and neuronal networks to respond to the environment is genetically determined. When neurons fire (are activated) they fire off neighbouring neurons connected via axons, synaptic gaps, and neurotransmitters. Repeated firing of particular neurons makes future firing more likely. Neurons that fire together are primed to repeatedly further fire together forming networks of neurons. These neural networks, if repeatedly activated, continue to develop further connections with other neurons and with other neural networks. 'Neurons that fire together wire together'. Such connections are the forerunners of memory systems in the brain.

The human brain is a very complicated three-pound mass of matter. It contains over 100 billion neurons and another one trillion support cells. There are up to 10,000 synapses on each neuron. Each neuron contains the entire genome and approximately 35,000 genes can have a direct impact on brain development (Grawe, 2007). The size of our brains, and those of our primate cousins, correlates with both the length of our juvenile period and the complexity of our social structure. Long childhoods and complex societies make for larger brains.

Likewise relational experiences, emotional experiences, verbal experiences, and thinking experiences are both registered in and made possible by brain activity. All this activity

represents growth and development in our brains made possible through our genetic potential, and made actual by our experiences in life. It is a clear example of a process where both nature and nurture are seen to be essential elements for normal growth and development to occur.

The right hemisphere generally processes nonverbal communication; it allows us to recognize faces and read facial expressions, and it connects us to other people. It thus processes the nonverbal visual cues exchanged between a mother and her baby. It also processes the musical component, or tone, of speech by which we convey emotion. Our right hemisphere dominates the activity of the brain for the first 2 years of our lives. Brain scans show that during the first 2 years of life, the mother principally communicates nonverbally with her own right hemisphere to reach her infant's right hemisphere.

The left hemisphere generally processes the verbal-linguistic elements of speech, as opposed to the emotional musical ones, and analyses problems using conscious processing. The left hemisphere dominates activity in the brain from 2 years onwards while language is actively developing.

### **Periods of rapid brain growth and development**

While the evolution of the structures of the brain has happened over millions of years, an individual's brain develops over a lifetime of about 85 years. There are three stages of particularly rapid brain growth and development during this time. The first stage is the time spent in the womb, when we develop from the joining of two cells at fertilisation, to a very complex living organism at birth nine months later. The second rapid stage of brain growth and development occurs during the first 3 years of life. The third stage of significant brain

development occurs during our adolescent years. The brain however continues to develop throughout life (Cozolino, 2006).

In the womb brain growth is rapid and complex. Nearing the end of the 9 months gestation period neurons are being added to the brain at a rate of 250,000 neurons per minute! The process of myelination, which maximises the transmission of impulses in nerves, is complete in areas of our brains controlling motor behaviour at birth. This growth and development is largely genetically determined but it is also influenced by events in the environment. Some environmental factors are highlighted in the following paragraph.

The outer layer of the cerebral cortex normally is comprised of six different types of nerve cells with differing functions. Nerve cells migrate to their allocated places during gestation. The presence of excessive alcohol and/or other drugs in the mother's blood stream compromises migration of these cells. An individual born in such circumstances may not therefore have a fully expressible potential at birth or at those times when the functioning of these specific nerve cell have an important contribution to make to brain growth and development. In a similar fashion high levels of circulating hormones can have a specific impact on brain development. High levels of male sex hormones, present for whatever reason, can "masculinise" the brain and also lead to the development of physical sexual characteristics more typical of males in genetically female infants. High levels of stress hormones (cortisol) in utero are particularly toxic to specific parts of the growing brain.

The brain continues to grow rapidly in the first three years of life. Infants are born with active primitive motor reflexes that become less obvious over the following weeks and months as the reflexes become mostly hidden by the development of new motor actions and capabilities. At birth infants have an active rooting reflex that will cause them to turn towards the nipple and breast to seek nourishment. They have a primitive smiling reflex that

kicks in to action in the early weeks after birth and helps to engage mother and others with them. They are primed to look at round faces and begin to make eye contact.

Over the following weeks and months infants engage in increasingly complex sensory, motor and relational experiences leading to the development of increasingly complex connections between neurons in the brain. Social engagement is a central aspect of an infant's experience in the first 18 months of life. This is both made possible by, and is responsible for, the very rapid growth of the Right Prefrontal Cortex (PFC) during the first 18 months of life. This rapid growth reflects the laying down in the Right PFC of patterns of attachment and social experiences that are central to the emotional development and well being of the child and of the future adolescent and adult. The Left PFC begins to grow more quickly from about 18 months to 3 years in line with the rapid development of language in the infant and child. Both left and right sides of the brain are connected by bundles of nerve fibres integrating the activities of both sides.

In adolescence the impact of surging hormone levels, bodily growth and development, is mirrored in the underlying growth and development of the brain. New social connections are continually being made in external life. These are reflected in the new neural connections and networks developed in specific areas of the brain. Adolescents are typically seen to be impulsive, poor longer-term planners, less considering of the consequences of behaviours, and emotionally labile. These features of adolescence result from the interaction of various new physical, emotional, and social challenges with a brain still in development and yet to complete the process of myelinisation in the prefrontal cortex of the brain. Myelinisation facilitates more effective and efficient transmission of nerve impulses in the brain. The PFC is ordinarily responsible for higher executive functioning of the adult brain such as planning,

anticipating, and linking actions to their likely consequences. These capacities are not therefore fully available to the young adult until the age of 25.

The brain continues to develop during our 'Adult Years'. All activities became much easier with practice. This is reflected in the degree of activity measurable in the brain. Many areas of the brain are seen to 'light up' on neuro-imaging when we attempt something new. With practice the areas and neural networks in the brain that are activated to achieve the same result become more defined and refined. Sometimes, as when motor movement and activity is involved, the necessary brain functioning takes place mostly in non-cortical brain areas such as areas in the brain stem and cerebellum. When some 'higher executive functioning' uses areas of the Pre-Frontal Cortex (PFC) to achieve a desired result, the area of the PFC used by adults is smaller to achieve the same result than that used by adolescents. Brain functioning becomes more efficient with practice.

Throughout adult life a small region of the hippocampus, the dentate gyrus, continues to generate new differentiated nerve cells from stem cells. Antidepressants may exert their effects on behaviour in part by stimulating the production of neurones in the hippocampus.

## **Mental Functioning**

### **Regulatory systems**

The brain is part of the nervous system as a whole that includes a number of regulatory systems. Regulatory systems in the body are involved in the maintenance of internal homeostatic processes, in balancing approach and avoidance, in balancing excitation and inhibition, and in balancing fight and flight responses. They also control metabolism, arousal, and immunological functioning. It is through these systems that we regulate our own, and each other's, biological and emotional states. The hypothalamic-pituitary-adrenal axis regulates the secretion of hormones involved with stress - the body's response to threat.

Immediate reaction to stress is vital for short-term survival, whereas rapid return to normalization after the threat has passed is essential for long-term survival.

The autonomic nervous system is controlled mainly by the hypothalamus and comprises of two sets of nerves: the sympathetic and parasympathetic nervous systems. Each of these two systems has a distinct anatomical location and communicates with its target organs through other neurons located in ganglia. The sympathetic nervous system goes into action to prepare the organism for physical or mental activity. When the organism faces a major stressor, it is the sympathetic nervous system that orchestrates the fight-or-flight response. It dilates the bronchi and the pupils, accelerates heart rate and respiration, and increases perspiration and arterial blood pressure, but reduces digestive activity. Two neurotransmitters are primarily associated with this system: adrenaline and noradrenaline. The activation of the parasympathetic nervous system causes a general slowdown in the body's functions in order to conserve energy. Whatever was dilated, accelerated, or increased by the sympathetic nervous system is contracted, decelerated, or decreased by the parasympathetic nervous system. The only things that the parasympathetic nervous system augments are digestive functions and sexual appetite. One neurotransmitter is primarily associated with this system: acetylcholine.

A 'Stress and Fear System' regulates levels of arousal, fight-flight, and approach-avoidance. Our experience of fear involves the amygdala alerting a variety of brain centres that a fight-flight response is required. The activation of the sympathetic branch of the autonomic nervous system results in symptoms of anxiety, agitation, and panic. The amygdala can pair stimuli and a fear response far ahead of conscious awareness. The orbito-medial-prefrontal cortex has an inhibitory relationship with the amygdala and can inhibit the amygdala based on conscious awareness. When we are very frightened the orbito-medial-prefrontal cortex

becomes inhibited, and we have a difficult time being rational, logical, and in control of our thoughts. The vagus nerve extends from the brainstem to multiple points within the body, including the heart, lungs, throat, and digestive system. Its sensory and motor fibres allow for rapid continuous feedback between brain and body. In the absence of external challenge, the vagus works to enhance digestion, growth, and social communication.

A 'Social Motivation or Reward System' is modulated by oxytocin, vasopressin, endogenous endorphins, and other neurochemicals related to reward, decreased physical pain, and feelings of well being. The social motivation system extends into the amygdala, anterior cingulate, and orbito-medial-prefrontal cortex and is thought to regulate proximity seeking, attachment, pair bonding, soothing, empathy, and altruistic behaviour. Bonding and attachment are regulated by peptides, vasopressin, and oxytocin. Attraction is regulated by dopamine and other catecholamines. Androgens and estrogens regulate the sex drive. The dopamine reward system of a sub cortical area known as the ventral striatum is involved with more complex analysis of social motivation. The activation of the ventral striatum translates the anticipation of reward into a physical impulse to approach. In this way, those whom we find attractive exert what feels like a gravitational pull on us.

Other regular and patterned functioning may be seen also as functional systems within the brain. These include the following: an 'engagement system' of affective regulation, fear modulation, stress reduction, and attachment schema; a 'social visual system' including orientation to faces, face recognition, direction of attention, and facial expressions; a 'mirror system' that regulates imitation, learning, communication coordination, resonance, empathy, and theory of mind; and a 'symbol system' of internal objects, words, metaphors and narratives.

## **Memory and learning**

Understanding memory as a representation and record of altered brain functioning is helpful in the context of learning. A child's brain functions very differently to an adult's brain. Memories and emotional reactions early in childhood are based on a more 'immature and primitive' mechanism of brain functioning. Brainstem reflexes and limbic activity organize much of the infant's experiences. Development of more primitive brain structures precedes the development of later-evolving ones. Early experiences influence the wiring that is installed in the brain, while later adult learning usually influences how already established wiring fires. Once neural networks are established new learning often relies on the modification of these established patterns.

The basic feature of the intercellular memory process is the pairing of neurons with each other. When two connecting neurons fire at the same time, they are more likely to fire together again in the future because the strength of the connections between them will be greater. When two connected neurons fire frequently together they develop new synaptic connections. These memory processes seem likely to be the basis for what is known as implicit (procedural, non-hippocampal) learning.

Simple repetition can effect change, even in the absence of reasoning or logic to support the change. The development of associations between events and emotions is an example of non-hippocampal learning based on simple pairing, even in the absence of awareness and insight. Non-hippocampal learning will not readily change despite the presence of new insight. When implicit memory associations weaken, they are likely to do so slowly and incrementally over time. Memory is highly influenced by affect.

Explicit memory is based in the hippocampus and affiliated structures. When two neurons both enervate a third neuron, the process of long-term potentiation can in effect form a bond

between them even though they are not directly connected. Pyramidal cells are neurons that receive input from extremely high numbers of other neurons. They are structured in a way that facilitates development of such new connections. These cells occur in high numbers in the hippocampus as well as in the outer surface layers of the cerebral cortex.

Connections between the hippocampus and frontal cortical areas appear to support conscious processing and decision making, and the area as whole is particularly well suited to establish novel connections supporting new learning. Hippocampal learning coincides with declarative and explicit conceptualisations of learning, while non-hippocampal learning coincides with implicit memory formation. Hippocampal learning supports efficient processing of incoming information and integration of new information with information previously stored in the brain. It also supports flexible retrieval of stored information (Solms and Turnbull, 2002).

The concept of the ‘remembered present’ suggests that much of what we take to be perception is in fact memory. We adults project our expectations onto the world all the time. We largely construct rather than perceive the world around us. Memory traces may be unconsciously activated all the time. One does not have to explicitly retrieve a memory for it to be active, and for it to influence cognition and behaviour.

### **Memory and Emotions**

The early sensory-motor and emotional memories of infants and toddlers are mediated via the amygdala, thalamus, cerebellum, and orbital medial prefrontal structures. This system organizes and retains primitive vestibular-sensory-emotional memories of early care taking, rendering them of permanent psychological significance. These early implicit memories come to serve as the emotional background against which subsequent psychological development takes place. When implicit memory is unconscious it cannot be thought about.

It can, however, be demonstrated via attitudes, beliefs, and behaviours. As the brain matures, the hippocampus, temporal lobes, and lateral prefrontal lobes begin to organize the systems of explicit memory. Hippocampal-cortical networks need to be functioning for the conscious recollection of the learning process. This usually happens somewhere between the ages of 3 and 4 years old.

The distinction between explicit and implicit mental processes applies to memory, learning, emotions, action control, motivation, emotion regulation and interpersonal behaviour. Implicit processes are independent of the capacity limitations of working memory. Many implicit processes can transpire simultaneously without interfering with one another. They typically transpire quickly and without effort, are not error prone and do not require attention and conscious awareness. They are typically linked to a specific sensory modality. They cannot easily, if at all, be controlled volitionally. They are typically learned more slowly than explicit memory contents. They need many repetitions to be learned. It is difficult to change them once they are well ingrained.

Lack of recall strongly suggests high levels of anxiety during childhood that mitigate against the consolidation of long-term memory. A lack of recall is associated with attachment styles that are anxious, ambivalent, and dismissing. Insecure and traumatized children have a difficult time self-regulating their emotions and suffer from anxiety, depression, and a variety of other symptoms. What the mind forgets, the body often remembers in the form of fear, pain, or physical illness.

The amygdala is a key component of emotional memory throughout life. The direct and rapid neural connections of the amygdala with the hypothalamus and limbic-motor circuits rapidly translate the rapid appraisal of threat into bodily states and action. The primary role of the amygdala in the social brain is to modulate vigilance and attention in order to gather

information, remember emotionally salient events and individuals, and prepare for action. The emotionally expressive face is an increasingly important transmitter of information across the social synapse. The amygdala networks with circuits throughout the brain to 'read' information from eyes, faces, direction of attention, gestures, body postures, and facial expressions. The amygdala becomes activated to both sad and happy faces but appears vital for recognising fear. Faces judged to be untrustworthy, as well as verbal and written threats, automatically activate areas of the amygdala.

The amygdala and orbit medial prefrontal cortex (OMPFC) are major players in the regulation of our experience of safety and danger. The amygdala connects negative experiences with autonomic arousal, generating anxiety, fear, panic, and flashbacks. The OMPFC assesses the reality of the danger and is capable of inhibiting the amygdala activation when a fear response is deemed unnecessary. The OMPFC and amygdala have a reciprocal regulatory relationship.

Evolution seems to be far more interested in keeping us alive than keeping us happy (Cozolino, 2006)! Overall negative emotions trump positive ones and weigh more heavily on our evaluation of people and situations. In a single highly charged affective moment any of us can learn to be terrified for the rests of our lives. Learning not to be afraid can take years of struggle. The amygdala is quick to learn and slow to forget. Learned fears are tenacious and tend to return when we are under stress. Based on our neurobiology fear outranks and outwits love in a number of ways. Fear is faster, automatic, unconscious, spontaneously generalised to other stimuli, multisensory, and resistant to extinction. Whereas the hippocampus is constantly remodeled to keep abreast of current environment changes, the role of the amygdala is to remember threat, generalize it to other possible threats, and carry it into the future.

Consciousness is understood from a neural perspective. We experience as conscious only those processes that occupy working memory for at least a few seconds. Working memory has a very limited capacity, is localized in the Prefrontal Cortex (PFC), and works in close collaboration with the anterior cingulate cortex, which plays a key role in the internal control of attention. The stream of consciousness is characterized temporally by continuity and simultaneously by consistency because the current content of working memory largely determines what will enter into working memory next. External events that enter the focus of attention also influence working memory. All forms of consciousness are linked to the associative cortex where internal connections far outweigh those that it has to and from the outside (by about 5 million to one!). The close interconnections of neurons and networks within the associative cortex are the main neuroanatomic bases for our subjective experience of consciousness and allow us to generate internal states that rely very little on external input.

### **Memory and Attachments**

Memory is intimately connected with the development of attachment patterns and behaviours. Communication across the social synapses between individuals occurs via smells that influence identification, attraction, and repulsion; via sounds such as grunts, groans, sighs, laughter, volume, tone, prosody, rhyming and song; via touch that influences affection, nurturance, grooming, sex, support, soothing and calming; and via visual impulses such as facial expressions, smiling, gestures, pupil dilation, and blushing. The activation of networks of the social brain by these multiple streams of information occurs in the internal systems facilitating interpersonal connection and regulation (Schoore, 1994).

These systems include the stress and fear systems that influence levels of arousal, fight/flight, approach-avoidance; the reward systems that regulate proximity seeking, bonding, attachment, soothing and social motivation; the engagement systems of affective regulation, fear modulation, stress reduction, and attachment schema; the social visual systems including

orientation to faces, face recognition, direction of attention, and facial expressions; the mirror systems that regulate imitation, learning, communication coordination, resonance, empathy, and theory of mind; and finally the symbol systems of internal objects, words, metaphors and narratives.

Positive social interactions result in increased metabolic activity, mRNA synthesis, and neural growth. Relationships can create an internal biological environment supportive of neural plasticity. Early neglect, stress, and trauma impact on all of the developmental processes discussed in negative and destructive ways. Neglect and abuse decrease the growth of experience-dependent neural circuits, especially of the orbito medial prefrontal cortex, anterior cingulate, and insula cortex. We are individuals but the architectural structures of our brains are records of our interpersonal histories.

Mirror neurons are neurons that fire when observing and performing a task. They are most likely involved in the learning of manual skills, the evolution of gestural communication, spoken language, group cohesion, and empathy. Thus we can learn by observation. Observing becomes a way to rehearse. Resonance behaviours, triggered by mirror systems, are automatic responses that are reflexive, implicit, and obligatory. Reflexively looking up or yawning when we see others do the same are examples. Therapists unconsciously mirror the facial expressions, tone of voice, and body postures of their clients. Resonance reactions occur before we are consciously aware of them. Fears, anxiety, and phobias can all be passed from one person to another especially from parents to children through observation.

The most important aspects of child rearing are, firstly, love and attachment, and secondly, being curious about who your children are. In this way you learn how to play with them, and how to encourage their imaginations. Every child is an experiment of nature. Children need

their parents' curiosity about them as an avenue of self-discovery. Attunement, secure attachment, curiosity, and affect regulation go hand in hand with neural plasticity in the brain.

This plasticity in the brain leads to a continuing capacity for learning throughout our lives. Eric Kandel (Kandel E R, 2003) was first to show that as we learn our individual neurons alter their shape and strengthen the synaptic connections between them. He was also first to demonstrate that when we form long-term memories, neurons change their anatomical shape and increase the number of synaptic connections they have to other neurons – work for which he won the Nobel Prize in 2000. Kandel demonstrated that appropriate spacing of learning is a key factor in developing long-term memory (Kandel E R, 2006) and that for short-term memories to become long-term a new protein has to be made. The more we use a skill like playing the piano the more space and brainpower it gets. Repetition alone isn't enough however for plastic change to occur. Close attention is also necessary.

Brain-derived neurotrophic factor (BDNF) plays a critical role in triggering the brain's ability to absorb and learn. When a child's body releases a lot of BDNF, keeping the brain constantly stimulated to absorb new information, the child's brain remains engaged and absorbent. At the end of a critical period, release of increased quantities of BDNF triggers an effective shut down of the critical period. We are designed to stop effortlessly learning past a certain point in adulthood, as it would be difficult to function if we were constantly distracted by new learning and therefore unable to determine priorities and 'accumulate wisdom'.

The brain's ability to grow new nerve cells, forge plastic change, and learn new skills isn't completely shut off in adults. There are three steps required to effect change in the brain. Firstly, considerable focus and attention are required to activate the nucleus basalis to produce acetylcholine and choline acetyltransferase, which in turn instructs the brain to fix

the memories being formed. Secondly, a mental challenge that leads to a sense of satisfaction and reward is also needed for the brain to produce dopamine, the second ingredient required for plastic change. Thirdly, targeted training is then required. Acetylcholine and dopamine prompt the growth of new nerve cells in the dentate gyrus of the hippocampus, and create conditions under which the brain can change. The way in which the brain actually grows and changes depends on what we're doing to stimulate that growth. Training exercises that strengthen and improve core brain functions can generate lasting improvements in our mental ability.

Many everyday activities stimulate neural growth and help us stay mentally fit. Studying a new language, tackling puzzles and brain teasers, or learning a new skill however isn't as directed and effective as that produced by a carefully designed brain training programme. The practical applications are many and varied. Learning specialists use brain-training software to help children reverse learning deficits. Senior centers offer brain training resources to their customers, reversing memory loss and delaying or preventing the onset of Alzheimer's symptoms and dementia. Progressive school systems have introduced brain training to help optimize classroom study. Individuals have taken to brain training as a way to maintain and improve their mental agility. The factors that can influence and train the brain to engage in and to gain maximally from psychotherapy now remain to be explored more fully.

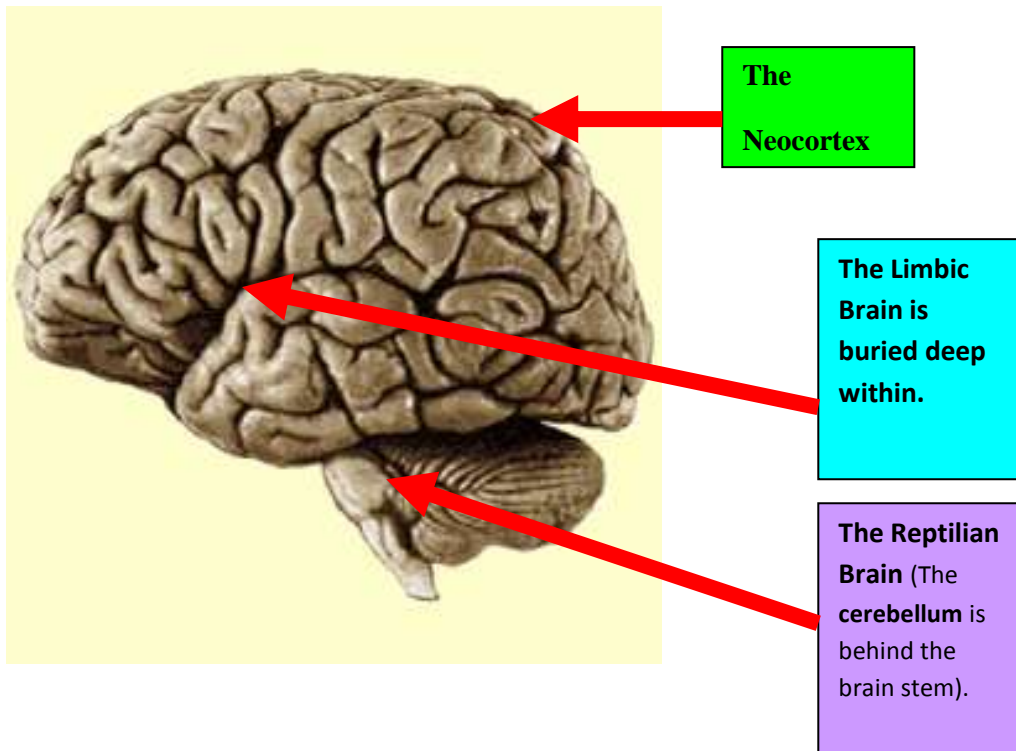
## **Conclusion**

I have attempted to follow on from Freud's Project for a Scientific Psychology by giving an overview of the rapidly expanding body of knowledge of brain development and mental functioning now available. I have highlighted some significant advances in genetics, in molecular biology, and in brain imaging that now make this possible. I have attempted to describe very complex issues in everyday language. My intention has been to stimulate ourselves as psychotherapists to be equipped with a knowledge base to be curious about brain development and mental functioning in our work with patients. This knowledge base comes with challenges to our ways of working as psychotherapists.

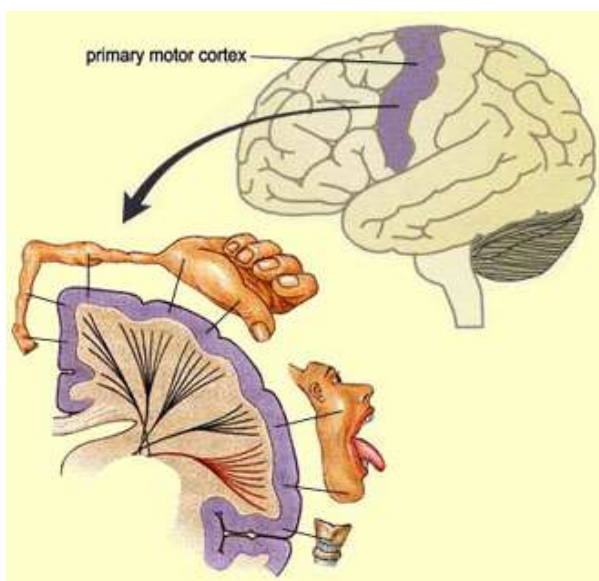
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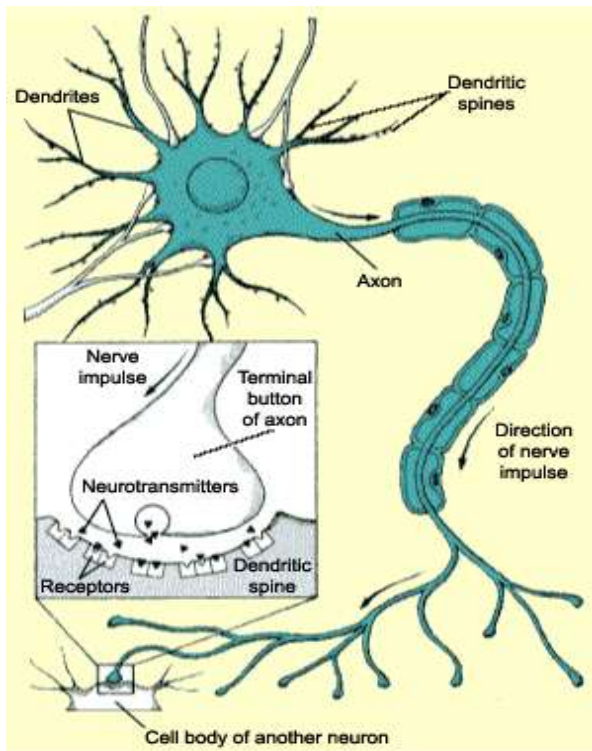
**Image 1: The Anatomy of the Triune Human Brain**



**Image 2: The representation of the body in specific areas of the brain**



**Image 3: The neuron is the building block of the brain**



**A Neuron**, with a cell body that contains genetic information, information (impulse) collecting **dendrites**, and an information (impulse) transmitting **axon** that is **myelinated** for speed of impulse transmission. A **synaptic gap** is inset.