Lifelong learning and developments in the brain sciences

"The brain is the last and grandest biological frontier, the most complex thing we have yet discovered in our universe. It contains hundreds of billions of cells interlinked through trillions of connections. The brain boggles the mind."[1]

Our mind-boggling brain

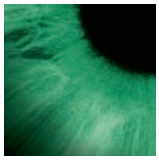
We now understand how neural connections form and create the pathways of memory and how learning and emotions are entwined

In the 21st century, scientists have achieved some amazing things. Geneticists have decoded human DNA and astronomers are able to view invisible galaxies through powerful lenses hurtling through space. After two decades of intense exploration, neuroscientists have also made tremendous strides and have begun to unlock the mystery and awesome power of the human brain. Educationalists are picking up on some of these insights as they gain a tantalising glimpse into how we make sense of the incredibly complex world into which we emerge at birth. How do we gradually become competent adults, each with the potential to make our own unique contribution to the sum of human knowledge? Although we are unique individuals, in one respect at least we are identical - our brains equip us biologically to learn from experience throughout our lives.

Modern neuroscience with its magnetic imaging of 'thoughts', and cognitive psychology with its exploration of 'internal states', are producing many challenging new theories about what is taking place between our ears when we talk, reflect, recall, solve problems and have ideas. Around 450 BC, Alcmaeon, an ancient Greek, was the first to discover that the brain was the seat of understanding. Aristotle argued that the organ of sensation and movement was the heart and that the brain existed merely as a heat extractor to cool the blood. Galen, a physician to the Roman gladiators, believed that a person's temperament was affected directly by the balance of various fluids in the brain, and his theory dominated for more than 1200 years. The Egyptians believed the heart was the essence of life and the source of good and evil, and discarded the brain when embalming. However, the heart and brain are profoundly connected, with constant communication going on. Some interesting theories are emerging from the study of this phenomenon, which is called 'heart math'.[2] Its research has identified a measurable physiological state that underlies optimal learning and performance.

Just as geneticists are finding that the more they delve the more mystery they uncover, so brain scientists equally are wrestling with complexity. Educators are beginning to try to use this knowledge to create better 'brain-friendly' ways of teaching. We now understand how neural connections form and create the pathways of memory and how learning and emotions are entwined. We know also that we have flexible 'learning' brains, which come with certain built-in preferences and strengths, but we only develop this potential when we are stimulated by a nurturing, social and cultural environment. Indeed, the human species is successful because we collaborate, adapt and respond creatively to new opportunities. With brain science providing a window to the brain as never before educators, such as leading international life-long learning expert Bill Lucas[3], are exploring creative ways to maximise the effectiveness of learning opportunities in the classroom. Chalk and talk are being replaced by much more engaging and active strategies that energise our brain's natural learning state.

Metaphors are at the heart of understanding complex ideas and various ones are used in this paper to throw light on the amazing capacity we have to develop our own intelligence. We will look at the brain in different ways - as a maze, a theatre, a theme park, a magic carpet and a pioneering trail. These are not new concepts, but they will be explored afresh through the lens of lifelong learning and developments in the brain sciences. Lifelong learning has been called "a survival concept for the 21st century" - vital for individual, social and economic well-being in a rapidly changing and complex world. Learning how your brain works and how to go with its natural flow will literally give you a 'head start'.



A biological maze

A maze of cells

Nothing in the known universe comes close to matching the complexity of the human brain. Put your two fists together – this is about the brain's actual size although insulation adds more bulk. The brain weighs around 1.4 kilos – about 2% of your body weight – and requires 20% of the oxygen you breathe. The wrinkled outer part, called the neo-cortex, has six layers and is the most advanced in evolutionary terms, governing higher-order capabilities, such as language, creativity and problem solving. Early scientists thought we had two brains just as we have two kidneys and two lungs. Of course, the brain has two quite distinct halves on the left and right of the head, joined at a wide flat junction just below the cortex called the corpus callosum. In the late 1960s, Roger Sperry's discovery that the two brain hemispheres had different dominant functions was a major breakthrough. At the corpus callosum, 300 million neurons or brain cells connect the two halves and their separate storage areas – a quite amazing dense neural maze! Most communication between the left and right brain happens at this junction in a constant back and forth frenzied flow of information.

The brain weighs around 1.4 kilos – about 2% of your body weight – and requires 20% of the oxygen you breathe

Neurons in the auditory cortex number around 100 million, smell receptor cells 12 million and cells in visual cortex an incredible 538 million. Your memory strengthens when you use different sense circuits by creating multiple 'storage sites', greatly increasing the chance of recall. Neural circuits can be reinforced or can decay, depending on how frequently we use them. The human brain is marvellous in its resilience and capacity for adaptation with the concept of brain 'plasticity' transforming neuroscience. This breakthrough is also good news for lifelong learning, as it implies that our brains can keep pace with new learning as we go through life, although we may learn differently and we may have to unlearn and put aside 'false' knowledge.

The evolutionary maze of three brains

In 1978, neurologist Paul MacLean proposed that the skull holds not one brain, but three, each representing a layer of our evolutionary history. They operate *"like three interconnected biological computers, each with its own special intelligence, its own subjectivity, its own sense of time and space and its own memory"*.[4] Reference has already been made to the wrinkled neo-cortex – the most advanced part that engages in the processes of thinking, learning, perception, awareness and judgment.

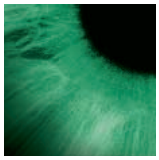
Nesting deep down in the middle is the limbic area or 'mammalian' brain, which closely resembles the brains of early mammals. It is very powerful, but not in a 'thinking' way. It processes emotions, instincts, feeding, fighting, reproduction and fleeing impulses. Below this, at the back of the head, is a small 'reptilian brain', sometimes called the 'Little Brain' which includes the brain stem and the cerebellum. In animals such as reptiles and fish, the 'Little Brain' dominates. It is not an adaptive brain like the neo-cortex, but a rigid, controlling one, sustaining unconscious functions such as balance, breathing and movement through the autonomic nervous system.

This idea of the tri-brain has been very influential, forcing a rethink about how much control the rational mind has. It been assumed previously that the neo-cortex was the great controller, capable of over-riding basic feelings. Maclean has shown that this is not the case and that the limbic system hijacks higher mental functions when it needs to. Although scientists now believe that this is an oversimplification, it is significant for learning, as it explains why it is difficult to take in new information or to make decisions under extreme stress or when you are uncomfortably hot, cold, tired, hungry or thirsty. It also underlines the evolutionary nature of our brain development that continues to this day. This is put succinctly and with humour by Ornstein and Sobel (1987):

"We carry our evolution inside us, within the different structures of the brain, structures built in different eras.... each one designed to maintain stability in its organism as animals moved from the sea to land, to the trees, to the savannahs of Eastern Africa, to Fifth Avenue."[5]

A branching maze

It is estimated that we have 100 billion brain cells and every one packs more punch than a desktop computer. Neurons are not conventional round cells but have branches called dendrites (the Greek word for tree) that stretch out to connect with other cells. They form a spiky fringe around the cell body, allowing each cell to receive signals from more than 100,000 others. Each neuron also has receiving appendages called axons that



transmit impulses to the dendrites of other neurons. They can extend for as much as three feet - the equivalent to a kite with a 40ft tail! The places on the cell wall where neurons transmit and receive messages are called synapses. A synapse is a tiny gap at the terminal of the axon across which an electro-chemical message jumps. Our thoughts and actions are the traffic of these signals between cells.

Neural connections are typically made in a dense tangle of axon terminals, dendrites and synapses, which together form a 'connectivity web'. It is the electrical activity in this neural maze that generates brainwaves that can be measured. So a thought is, in effect, an electro-chemical event. We share this phenomenal communication system with other animals from the jellyfish up.

In humans, each cell has between 1000 and 10,000 branching connections to other cells, creating a network of a million billion connections. This number is so large that it outstrips the number of particles in the known universe. This profusion of connecting cells allows us to capture our experience rather like a digital video camera records scenes, events, faces, voices, sounds and sights on disk. The difference is that our 'disk' has limitless capacity - our neo-cortex will never run out of space! But we do need to focus, organise and reflect on our experience if we are to have any hope of not being overwhelmed and confused by the volume of information bombarding our brains.

...we construct an understanding of who we are, what the world is like, what is good for us and what we don't want

Finding a way through the maze

As we store memories of our experiences and reflect on what is important, we construct an understanding of who we are, what the world is like, what is good for us and what we don't want. We learn to build a uniquely individual intelligent view of the world, which guides each of us as we plan the future, build relationships and make new discoveries. Over time, we beat familiar pathways through the brain maze and develop habits of thinking that become our reality and part of our personality.

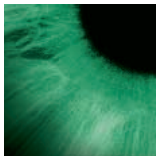
Jean Piaget, the great 20th century pioneer of cognitive development, whose mission was to discover how knowledge grows, commented: *"Intelligence is what you use when you don't know what to do"*. An ancient Chinese proverb puts it another way: *"Those who want to do something find a way"*. Human development is characterised by people inventing new things, from the wheel to the iPod, and leaving a legacy to future generations. The rate of inventions is now accelerating and, when you buy a new gadget, you know someone somewhere has a prototype of the next great gizmo on the drawing board! As Bill Gates put it: *"In the world of technology, it's a story of constant revolution."*

But inventiveness in humans is not limited to technology and science – music, art, drama and stories shape the way we see life. Imagine living in a world without new films, books or television programmes, or a world without laws to order society. But laws need to change to meet new needs and new perceptions of justice. New situations, such as global warming, need innovative action. And the amazing thing is that each one of us has a totally unique configuration of brain cells that is capable of producing new ideas to make life better for ourselves and others. Author, lecturer and adviser on the brain and thinking skills, Tony Buzan, has probably done more than anyone to promote the idea that everyone can develop their unique 'mind genius'. [6]

Amazing brain juices

"Scientific revolutions are very interesting. The way they happen is that most people deny them and resist them. And then there's more and more of an explosion, and there's a paradigm shift".[7]

Pert's landmark work on the biochemical pathways of the brain helped to spark the neuroscience explosion that led to the knowledge that the mind and body are one, with the same chemical messengers or neurotransmitters. There is overwhelming evidence that our bodies react to suggestion, not to reality, and that even a broken leg mends at a rate linked to our attitudes, hopes and fears. Neurotransmitters are the versatile molecules that chemically connect neurons at the synapses and relay messages not just to other brain cells but to other parts of the body. Extremely small amounts subtly underlie all our moods, from ecstasy to deepest depression.



Dopamine, norerepinephrine and serotonin are the main mood-elevating neurotransmitters. These opiate-like endorphins trigger an increased flow of acetylcholine - the lubricant that allows neural networks to grow and memories to be captured. Listening to a glorious piece of music, experiencing a breathtaking sunset, sharing a good joke, stroking an animal, enjoying a wonderful walk and mastering something challenging are events that give us a chemical 'brain bath', which accounts for the pleasurable feelings that accompany these activities and make them unforgettable.

Maintaining the maze

Brain foods

The brain needs the right conditions to perform all of its vital functions. Staying physically and mentally active increase and preserve brainpower, but so too can the foods you eat if you make the right choices. There is considerable research around nutrients that are good for the grey matter. In a study of people aged 65 and older, leafy greens (spinach, kale, greens, lettuce) were declared the hands-down winners when it came to preserving brain function. Also near the top of the list were zucchini, squash, eggplant, and broccoli.

Each of your 100 billion brain cells uses oxygen at a rate 10 times greater than the rest of your body

What makes these vegetables so good? Probably brain-friendly nutrients like vitamin E, carotenoids (the yellow, orange and red pigments synthesised by plants), flavonoids (a large family of plant chemicals) and antioxidants. Oxygen makes life possible, but it can also take life away. Each of your 100 billion brain cells uses oxygen at a rate 10 times greater than the rest of your body, but this same oxygen can erode the very structure of those cells. Micronutrients from food are the antioxidants your brain relies on to safeguard it from damage and malfunction. Eat your leafy greens with a little olive oil (contains abundant antioxidants rich in polyphenols) or a sprinkling of nuts or a portion of oily fish (Omega 3) to help your body absorb and use all those valuable, fat-soluble nutrients. There are many excellent independent websites that provide detailed advice (and even recipes) based on results from research studies on optimum brain nutrition. Essentially, fats build your brain and proteins unite it. Carbohydrates fuel your brain and micronutrients defend it.

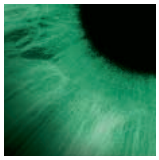
Fluids

Eighty five per cent of brain tissue is water, so dehydration slows the brain right down. In fact, studies have linked depression and chronic fatigue syndrome with dehydration. By the time you feel thirsty, your brain is already cranking down a gear. Much of life is habit, so get into the way of having drinking water to hand throughout the day. Water also helps with the digestion and absorption of food and in transporting oxygen and nutrients to the cells. Although we tend to chill drinks, water is best taken at room temperature, as the brain has to divert energy to the stomach if a sudden influx of cold water begins to cool the system.

Sleep

The brain maze needs to cut back on the constant daily traffic. Although it is humming away 24/7, we need down time for rejuvenation. Sleep deprivation adversely affects the electrical patterns in the neo-cortex causing differences in how we think, not only at the time, but into the next day. Sleep deprivation can also have a retrospective effect. One study showed that students who studied hard all week and then stayed up all night partying at the weekend lost as much as 30% of what they had learned during the week. Alcohol and memory loss also go hand in hand, so partying all night is a double whammy and a high price to pay for a good time.

In this section, we have seen how brain research is unravelling the mysteries of brain architecture. It is so ingenious that no one could invent a machine with such flexibility, responsiveness, overlapping pathways and unfathomable capacity. In the past, the brain has been compared to a bio-computer, but many neuro-physiologists, cognitive scientists, information theorists and memory psychologists have abandoned this metaphor. Instead, the brain is better described as a self-organising system that is responsive to its environment. It is not only a thinking brain but a 'feeling' brain – a fact that has huge implications for learning. This is the focus of the next section.



A theatre: the emotional brain

"All the world's a stage,
And all the men and women merely players."
Shakespeare, As You Like It, 2. 7.

By now, you should have a fair idea of your brain's evolutionary multi-layered system. Apart from the sophisticated cerebral cortex that allows you to build your intellect, you have inherited a mammalian brain with important functions - setting the emotional tone of the mind, generating emotional reactions linked to survival, storing charged emotional memories, motivating, influencing appetite and sleep, and promoting bonding. It is also the gateway to long-term memory. Because of its primitive nature, it has the potential to over-ride your rational brain and make you to behave in ways you may regret! This makes the emotional brain the perfect candidate for the theatrical metaphor. What better context than Shakespearian theatre to observe the tragedy (or comedy) of human existence when people's irrational feelings and misperceptions lead them to make the most tragic or crazy mistakes.

There is also a sense in which we see our own life as a passing play, full of mystery and magic, and where we came from and where we go will only be known when we get there. However, understanding the role of emotions and managing our emotions is a lifelong task. We learn through living to manage more skilfully the strong, potentially destructive feelings that are part of our biology. The challenge is not to fall into the trap of being 'mere players' controlled by a 'biological' script. Our emotions are tuned by upbringing, schooling, the role models of our early years and the norms expected in a civilised society. But how we deal with frustration, disappointment, rejection, conflict, competition and difficulty has a huge bearing on how successfully we will be perform as lifelong learners.

Our emotions are tuned by upbringing, schooling, the role models of our early years and the norms expected in a civilised society

The power of emotions

"The really important genes are not the ones which tell us what to do, but the ones which give us the ability to change behaviour in response to our environment." [8]

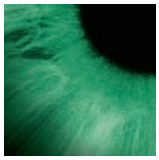
It is useful to understand a little about the limbic system, although it is important to remember that all brain functions are bound up together and operate as a holistic body-brain system. The mammalian brain is a group of cellular structures sandwiched between the brainstem and the cortex and linked to the pea-sized pituitary gland, the master gland of the hormonal system. The hypothalamus is the bundle of nerve fibres of our pleasure centre or reward circuit and it drives much of our goal-seeking behaviour. This is where we develop our addictions to chocolate and alcohol. A simple smile also reflects neurotransmitter activity deep inside the hypothalamus.

The amygdala, on the other hand, is the key limbic structure for the co-ordination of behavioural, immunological and neuroendocrine responses to environmental threats. The amygdala compares new, incoming sensory information with information already stored in the emotional memory bank. It then makes a split-second decision about the potential threat. Since it has extensive connections to the autonomic nervous system in the 'reptilian brain', the amygdala can 'hijack' other neural pathways, activating an emotional response before our higher brain centre receives the sensory input.

The hippocampus is critical for transferring information from working memory to long-term memory. It is vulnerable to cortisol damage from unremitting stress. This can cause it to shrink irreversibly over time, creating concerning memory problems.

Adverse reactions

So what is the significance of the limbic system for learners? As stored emotional memory patterns affect our moment-to-moment perceptions, emotions and behaviours, a learner may find that the new tutor who walks through the door reminds her of another teacher with whom she had a bad experience, or a bully from school, or the person at work who upsets her. This immediately generates an emotional thought or feeling – 'emotional' in that she 'sees' the new person as if he actually were that 'bad' person. Adverse mental reactions and emotional responses can generate instantaneous physiological changes in the autonomic nervous system, hormonal and



immune systems, which have very real effects throughout the entire body and brain. Plato, the Greek philosopher, said: *"All learning has an emotional base"* and when we look at the concept of emotional memory, we can understand why.

Awareness

We can't control 'limbic' reactions because they are built into our brain's hard-wiring. But with insight we can recognise this for what it is and think again. How many people have returned to adult learning and relived unpleasant feelings of rejection from their school days as they sit in a classroom and feel their stress levels rising? They may simply take the first opportunity to flee from these uncomfortable feelings and never return. Teachers need to make a concerted effort to be especially friendly, approachable, open and non-threatening, particularly at the early stages of any return to learning. When the present is an unknown quantity and the future is uncharted territory, triggering the memory of a bad emotional experience may jeopardise the whole enterprise.

Neurologists now stress the rationality of emotion and the importance of emotions in decision-making

Interacting systems

Contrary to popular belief, emotions are not always negative and do not always serve as opponents to rational thought. Instead, emotion and cognition can best be thought of as interacting systems, each with its own type of intelligence. Neurologists now stress the rationality of emotion and the importance of emotions in decision-making. Emotional intelligence, for example, is an essential skill in leadership. It is known that, if the brain is injured in the areas that integrate emotional and cognitive systems, a person can no longer function properly even though their mental abilities are intact.

"Emotional intelligence is the ability to perceive emotions, to access and generate emotions so as to assist thought, to understand emotions and emotional knowledge, and to reflectively regulate emotions so as to promote emotional and intellectual growth."[9]

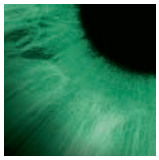
Coherence

Studies show that the key to the successful integration of the mind and emotions is in bringing them into harmony with one another. Within the wiring of the brain, the neural connections from the limbic system upward to the neo-cortex are stronger and more numerous than the connections from the neo-cortex down to the limbic. Once an emotion is experienced, it becomes a powerful motivator of future behaviours, affecting our moment-to-moment actions, attitudes and long-term achievements. Therefore, the emotional tone in a learning situation is not just an added extra. No one teaches in an emotional vacuum. The teacher who generates a feeling of confidence and success, uses humour and praise, makes learners feel valued and appreciated and amplifies good feelings, is laying down a lasting trace in the emotional memory bank that will stand learners in good stead and make them more resilient when problems occur.

Creating the conditions of coherence between mind and emotions has been shown to improve vision, listening abilities, reaction times, mental clarity, feeling states and sensitivities. The heart also has its own neurotransmitters that send messages to the brain. The study of how to calm the brain through focus on the heart is the core purpose of HeartMath, which uses simple powerful techniques to help people quickly moderate the raging limbic system before damage is done to the self and to others. HeartMath research has identified a measurable physiological state that underlies optimal learning and performance. So the early Egyptians with their focus on the heart were not so far off the mark!

Memory enhancement

It is also significant that the limbic system controls not only emotions but memory. Positive emotions play such an important part in transferring learning into long-term memory. If learners find an experience enjoyable they will recall facts more readily. Collaboration, group discussion, active participation, games and quizzes will create



a state of positive emotional arousal, releasing a flood of 'pleasure chemicals' that help to 'fix' facts in memory. On the other side of the coin, there is growing evidence of the benefits to be gained from learning to manage stress to increase physiological, mental and emotional coherence. This points to the importance of being able to self regulate emotions. In the light of this new understanding of its critical role in successful learning, emotional intelligence and managing stress should be on the agenda of every programme on learning how to learn.

In this section, we have explored the influence of our emotional state on our ability to absorb new information and how our emotions are part and parcel of our biological inheritance, to keep us from harm and to bind us to others. Our emotions can be a help or a hindrance when we are learning, but by taking steps to improve our emotional awareness we can mitigate their worst effects and maximise their creative power. In the final section, we briefly review developments in the brain sciences through the lens of lifelong learning and look at some of tools and techniques that are being applied successfully.

Section 3

It is crucial to appreciate the value of breaking learning into chunks, with downtime and rewards for perseverance

A magic carpet, a theme park, a pioneering trail

"Good lifelong learning practice takes away those limitations - that people impose on themselves - and provides the new tools, techniques and motivations to learn."[10]

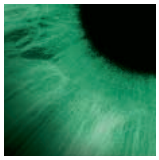
Brain research suggests that, as long as a normal brain is not constrained from fulfilling its everyday processes, learning will happen naturally and easily. At the beginning of the 20th century, the first IQ test was created in Paris. Intended as a means of helping children with special educational needs, its ideas spread like wildfire. Unfortunately, it scattered the seeds of some corrosive thinking. It suggested, firstly, a scarcity of talent; secondly, talent is largely fixed; thirdly, it is limited in its scope. In fact, there is no shortage of talent as it is inherent in all human beings. Failing to unlock or stultifying an individual's potential is an appalling waste.

Harvard education professor Howard Gardner maintains that it is a crucial blunder to assume IQ is a single fixed entity. His contention is that we have a repertoire of skills for solving different kinds of problems in different settings. Using insights from neuroscience (especially the work of Sperry) as well as inspiration from other disciplines, he developed the concept of multiple intelligences. This sees the brain as a kind of multi-dimensional theme park with a range of competences that we can dip into, from the verbal and mathematical to interpersonal and musical. Although we probably have a tendency towards certain styles of thinking that are left brain (logical, sequential, rational, analytic, objective) or right brain (random, intuitive, holistic, synthesizing, subjective), thinking is a whole brain activity. Teachers who foster a whole-brained learning approach use instructions that connect both sides of the brain. Therefore, they incorporate patterning, metaphors, analogies, role-playing, visuals and movement into their reading, calculation and analytical activities.

Awareness of your range of talents or your 'signature themes' comes under the rubric of metacognition – learning how to learn. Aspects of metacognition include learning styles linked to Kolb's learning cycle, identifying your strongest sensory modality (visual, auditory or kinesthetic) and learning practical strategies for reinforcing memory, such as mnemonics or mind mapping. It is crucial to appreciate the value of breaking learning into chunks, with downtime and rewards for perseverance. Raising awareness of the range of tools to make learning stick and your own learning style and preferences gives you an immense head start.

Because human actions are goal-oriented, the feelings and thoughts about the learning task will send us soaring over obstacles towards success or turn us into plodders. One of the very practical areas of development in this field is the positive psychology of neuro-linguistic programming (NLP). This capitalised on the power of positive emotions to energise and release the 'happiness chemicals' that anchor learning in long-term memory. An optimistic outlook with a flexible plan, a vision of a successful outcome and a willingness to use the language of success (no failure only feedback), is like having a magic carpet that will take you where you want to go. With this mind-set, you develop your motivation, your capacity to co-operate, influence those around you for good and create your own success story in your own terms.

Now we come to the final metaphor – the pioneer trail. This incorporates Einstein's belief that ideas are more important than knowledge. The imaginative brain is not the preserve of the talented few. In whatever roles we



find ourselves there are possibilities to make a difference. Ideas often seem to appear from nowhere - from a radio play, a painting, a piece of music. Einstein's theory of relativity came to him in a dream about a sunbeam. Tony Buzan swears by the creativity of free association. Young Anne Frank kept a remarkable diary during World War Two that has been translated into 67 languages and is one of the most widely read books in the world. She died aged 15 in extreme adversity but she had maintained her creative mentality, her coherence, her affirmation of life, and continued to question what was going on. She was a true pioneer and inspirational figure and wrote: *"When I write, I can shake off all my cares."*

In this paper, we have explored some of the new possibilities of lifelong learning. We have an incredible resource in the human brain and we must challenge a system that results in great numbers of human beings demotivated by a belief that they have little talent for learning. Our brain biology hardwires us to learn and developing an understanding and confidence in our own unique view of the world is the foundation of success in learning and in life.

Einstein's theory of relativity came to him in a dream about a sunbeam

References

1. James D. Watson - Discovering the Brain, 1992

2. Childre, Doc & Howard, Martin. The HeartMath Solution: Piatkus, 2000

3. Lucas, Bill. Power Up Your Mind. London, Nicholas Brealey Publishing, 2001

4. Paul MacLean – The Triune Brain, 1978

5. Ornstein and Sobel (1987) quoted in Understanding a Brain-Based Approach to Learning and Teaching, Renate & Geoffrey Caine, Educational Leadership, 1990

6. Tony Buzan - Use Your Head, 2003

7. Candace Pert - Molecules of Emotion, 1986

8. David Suzuki - Naked Ape to Superspecies, 1999

9. Jack Mayer, Peter Salovey & David Caruso, D. (2000) - Models of emotional intelligence. In R.J. Sternberg (Ed.), The handbook of intelligence (pp. 396-420)

10. Norman Longworth. Lifelong Learning in Action – Transforming Education in the 21st Century, 2003

Websites

The websites below are a rich source of further information about the discoveries of neuroscience.

Health – the Body - How Your Brain Works by Dr Craig C. Freudenrich.
http://health.howstuffworks.com/brain7.htm

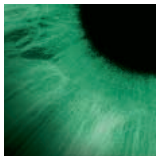
The Franklin Institute Online – the Human Brain – Micronutrients
http://www.fi.edu/brain/micro.htm

The Linus Pauling Institute, Oregon State University – Micronutrient Research for Optimum Health – Phytochemicals – Carotenoids
http://lpi.oregonstate.edu/infocenter/phytochemicals/carotenoids

Healthy Food and Nutrition section – drinking water
http://www.healthrecipes.com/drinking_water.htm

The Sleep Foundation, Indiana Regional Medical Center, 10 sleep tips.
http://www.sleepfoundation.org/hottopics

Learning Discoveries, Rosemary Boon
http://home.iprimus.com.au/rboon/HeartRhythmsandHRV.htm



The Brain from Top to Bottom
http://thebrain.mcgill.ca/flash/index_d.html

The Brain Connection The Limbic System
www.brainconnection.com

Heartmath
www.heartmath.com

Author

Val Bissland
Centre for Lifelong Learning, Strathclyde University

This paper is part of the Learning Principles series, which aims to provide accessible and practical information for staff in learndirect scotland branded learning centres.

Each document highlights best practice to help people to learn and stay learning.

The series covers a range of themes including sensory impairment, learning difficulties, brain sciences and working with deaf learners.

Learning Principles papers are available in pdf and plain text formats at:

www.lds4partners.com

For more information, contact:

learndirect scotland
Alhambra House, 45 Waterloo Street
Glasgow G2 6HS
Tel: 0141 285 6000
Fax: 0141 285 6001
Email: enquiries@learndirectscotland.com