UNLOCKING
CONSCIOUSNESS

# APPENDIX 045

## DEFINITIONS OF MEMORY. ROLE OF WORDS

*A fundamental attribute of the brain is the ability to learn and remember. To better understand how the brain does this we need to categorise, describe and develop some Definitions of what we mean by 'Learning, Memory, Meaning and Words'.*

*"Language creates reality*
*If you have not got a word for it, you cannot know it."*

Wittgenstein

How the brain forms and retrieves memories lies at the foundation of almost every aspect of how the brain operates. Without memory it is difficult to see how we could be conscious. How we form memories is key to understanding how we learn and therefore is the basis of education. Discovering how we retrieve memories is the starting point to study memory loss and ways and means to combat the various forms of dementia. Knowledge of how memory operates will greatly advance our understanding of many brain conditions from autism and dyslexia to schizophrenia and psychosis.

**Before we can understand the solution, we need to understand the problem.**

Huge advances have been made in recent decades in our understanding of the electrochemical physical structure of the brain, but before we can advance much further we need a clear, concise set of definitions of what a memory is. Is there one generalised memory system, or have a variety of systems evolved to carry out specific tasks, learn information, or store experiences, for instance? How are memories formed (temporary and short-term memories, long term memories and how are memories strengthened, modified and edited)? How are memories recalled and forgotten (temporarily, permanently and optionally)? How do memories operate and how is information recognised? In turn, this means that we need to define information and how it is processed in the brain and nervous system. Last but not least, we need to define how memories and information have meaning.

We can start with a very simple observation. When we discover, learn and remember some piece of information or task something changes. After we have added that new piece of knowledge the state of the brain is different. What has changed?

**At birth we can do almost nothing, but our brain enables us to learn to remember to do almost anything.**

It is not an exaggeration to say that the brain has evolved primarily as a 'learning system'. Every child is born with well over two billion neurons capable of transmitting electrical signals along their axon and dendrite filaments, connecting up all the organs of its body. About half are concentrated in the brain. The neuron networks in the body do not change a great deal over a lifetime, but a mature brain has grown a trillion further links and networks. In addition, there are more free-floating glia cells in the brain than neurons. The whole brain is bathed in a chemical solution including varying amounts of hormones, neurotransmitters and messenger molecules among others.

The brain grows a thousand-fold at least. These additional structures are the records: memories of our accumulated experiences. We can observe that the brain appears to have an almost infinite capacity. We continue to learn throughout our lives. A wide spectrum of tasks, information and experiences from our earliest childhood accumulate throughout life. The limit of human recall has yet to be found. To measure the volume of what we remember is extremely difficult. Even finding a formula is very hard. For example, most people can readily recall, speak and write twenty thousand individual words, some can recall over one hundred thousand; and that is just in one language. No other life form has anywhere near this scale of capacity. How is it that the brain operates so that its memories are never 'full'?

*We can make a first stab at a simple definition of these memories:-*

*Biological memories are patterns of electrochemical physical neural structures that develop in the brain in configurations that on each occasion that they are recalled, or stimulated, induce a repetition of the original sensations, and neural signals directly or indirectly activating muscles, glands or other neurons.*

## Types of Memories

There is considerable debate over whether we have one generalised system of memory or many different types. The current consensus favours three distinct types of memories. Firstly there are sets of instructions: neural networks that drive the muscles to carry out various physical activities. They carry out processes and are usually called '*procedural* memories'. Much research has shown that, say, expert violinists have substantially enhanced motor neuron structures associated with the muscles of the arms and fingers.**[Tulving]

Secondly there are neural networks that are not connected to muscles, but are principally connected to other neural structures. These are usually called '*semantic* memories' because they store information. Research shows the brains of taxi drivers who have mastered 'the knowledge' are significantly enhanced.

The third category is records of our experiences – episodes in our lives, and therefore named '*episodic* memories'. We can observe that every time that experience is repeated the potential is there to update the record of that activity. Just to add to the complexity, we store experiences of actual events, or incidents that have <u>*not*</u> happened to us, but where we have participated vicariously – drama, plays, films that we have witnessed of other people's experiences, and novels and stories that we have merely been told about. They can be reality, complete figments of our imagination, or a mixture of both; or even what we wish had occurred. Episodic memories appear to be include procedural and semantic memories plus the invented creations of our imaginations – conscious projection and planning. However we categorise them, all three appear to conform to our first definition above. If there are three separate algorithms, they all share the same paradigm.

Semantic Memory (Information)

The easiest category of memories to explore are those currently categorised as 'semantic memories of information' as they encapsulate language. One starting point is to look at what is involved in the definition of the memory of just one single word.

Before we can determine a basic definition of a neural memory of a 'word' we need to define what we mean by a 'word'.

***We can define a word*** *for this purpose as a pattern of sound waves that a group of people can speak and hear, or visual images that they can read and write: that they can recognise and has a generally accepted meaning.*

***Thus a basic definition of a neural memory of a word*** *is a pattern of electrochemical physical neural structures developed in the brain, that on every occasion that this configuration is stimulated causes the vocal systems to generate a pattern of sound, or the muscles to draw a visual image, that can stimulate a similar pattern of electrochemical physical neural reactions in the brain of another person.*

This is a very limited definition of a neural memory of a word. We need to define a great deal more. The definition must incorporate much more, and include all the variations of each word. For instance:-

1. The neural structure of the pattern of sound waves 'heard' by the eardrums and how they stimulate the pattern of electrochemical physical neural structures in the brain which can generate the pattern of instructions to
2. Manipulate the muscles of the lungs, vocal chords, throat, mouth, lips and tongue to speak that word – this is straying into procedural memory.
3. The neural structures to see and 'read' the visual patterns of the printed and written letters that spell that word; and
4. The pattern of instructions to manipulate the muscles of the arms, wrist and fingers to draw the characters of the letters and 'write' that word – also procedural.

That begins to address the input and output of a word. Then we need to move on to the processing associated with a word. For a word to have any 'meaning' we need to define how networks are connected to neural structures representing the:-

5. – 10. Five sensory systems, for which words are descriptors or labels, and the whole range of

11. Emotional reactions, and
12. Sensations generated by words.
13. Not only can we link words to the many images like 'tree' etc, but we have a feeling for the relative
14. Size of a number, or a word like a 'million'.

15. Then there are the links to the representations of all the other neural structures for other words that are related, cross referenced to, or otherwise associated.
16. In addition we can observe that the memory of a word includes information about the occasions we have 'used' those words, and when
17. Other people have 'said' those words to us and
18. Their effects and implications, and
19. The impact on our relationship with them, and so forth and so on. These last four descriptions overlap with episodic memory.

Then there is another category. Observably we can store the alphabet, numbers, punctuation and symbols.

20. We need to define how words are deconstructed into letters, syllables and phonemes and how we string together the appropriate components to spell the spoken and written word.

21. Similarly, how do we assemble and string together sequences of words so that we can recite them fluently? Observably the same word is used in many different situations, yet its use in one sequence does not interfere with its use in other sequences.

22. How do we invent new words and all their associated meanings?

23. Certain words can be used together, while other words can not be used together: for instance adjectives with nouns but not with verbs. A new adjective can be linked to many nouns – adverbs to many verbs: How are these new links created? This opens up the whole subject of syntax and semantics. A massive subject on its own.

24. How are the rules of grammar replicated in the brain?

25. We frequently have two or many more words that mean very nearly the same. Horse, stallion, mount, mare, thoroughbred, foal, colt, pony steed charger, blacksmith. How are they both linked and differentiated?

26. Then there are multiple languages. How are we able to utilize two or more languages, relate and translate one into another and switch between them?

This list is not exhaustive. No definition of a 'word' is complete without reference to the observation that the meaning of words is influenced by whether it is alone or in combinations of two, three or many more words in phrases and sentences. Similarly the meaning of a word can change according to its position in a phrase.

We need to address at a more subtle level how the same word can have different meanings in different situations, and how the meaning of a word can be changed, even reversed, by the way in which it is enunciated. This is true of all languages, but particularly so of some languages of which Chinese is the most well known.

> *Note*. There is another aspect of words that is of very considerable significance, but will be addressed later. It is possible to talk silently to ourselves and hear with perfect clarity words that have not been spoken.

The first step is to define 'what' the brain processes and records. Only then can we begin to define 'how' the brain records this and forms memories.

## Information and Knowledge

There are two words in the English language to describe what we think the brain processes and records: 'information' and 'knowledge'. Information generally suggests facts like descriptions and measurements. Knowledge suggests attributes that are much broader, and includes concepts like the meaning of information, and the implications and extrapolation of information, and the use of information to solve problems.

This suggests that there are five aspects of this type of memory that need definition:-

1. A biological memory
2. The formation of a memory of information
3. The recognition of incoming information
4. The recall of a memory
5. The meaning or knowledge encapsulated in memories.

Definition 'two' addresses the basic question of what changes when we acquire an additional memory.

Definition 'four' must also address the failure to recognise familiar information and the temporary or progressive failure to recall known information.

All four depend on a

## Definition of biological information.

It can be argued that there are only two systems in the world capable of processing and storing general purpose information that we know about. One is the human brain and the other is the computer. Computers[1] can be an exceedingly misleading analogy for the brain, but together with telecommunications, computing has helped us learn a very great deal about information. It is a widely held opinion that thanks to '*information technology*' we are on the cusp of having the entire body of human knowledge, art, culture and commerce instantly available to everyone.

The first great breakthrough to cope with information was the invention of writing: we learned to make marks on clay tablets that could be universally recognised as having meaning. Alphabets developed to encode sounds, thus every human word, idea and concept could be expressed as patterns using a mere twenty six symbols and every number with just ten symbols. Galileo expressed this best. "*Of all the stupendous inventions, they who conceived how to communicate their most secret thoughts distant in time and place simply by the arrangement of two dozen signs upon a paper".*

Claude Shannon showed that all information can be described by patterns of binary units or 'bits': a hole in a punched card or no hole: a pulse or no pulse: the ubiquitous '0' or '1'. All the letters and numbers can be accommodated in patterns using just eight bits ($2^8$ gives 256 variables) usually referred to as 'bytes'. Not only alphabets, numerals and symbols but most music and many visual images are now stored, processed and transmitted in this form, thus all human knowledge is encapsulated in binary digital codes based on the Morse code. Complex systems like the weather, or the economy can be expressed as mathematical models just using patterns of bits.

Computers store and process these codes strictly according to a hierarchy of rule based algorithms which we think of as programs – actually computers can do nothing else! Shannon's defined a 'bit' as the smallest measurable unit of information, which was a major breakthrough for the technology of accurately transmitting messages over communications systems. However, as a definition of information it is incomplete, because it expressly excludes any reference to meaning. In fact a 'bit' is the smallest measureable unit only of 'machine information', or perhaps we should say 'artificial information' to stay congruent with the related computer term 'artificial intelligence'.

All these codes whether, alphabets, numerals, symbols or digital binary bits only have meaning to us, because we have invented them. Should we ever meet people from another planet our entire corpus of human knowledge would mean nothing at all to them unless they could decipher these codes. Telecommunications equipment and computers can store and process limitless amounts of digital information but have no concept of knowledge at all. The nearest computers get to knowledge is the ability to store a description of one set of digital codes in terms of another set of digital codes: the 'meaning' of one word in terms of a string of other words, [dictionary description] or by adding pictures [encyclopaedia description] or as measurements.

Biological information is not the same. The only example of a biological coding system that appears to be similar is in Deoxyribo Nucleic Acid (DNA), which involves four variables (cytosine, adenine, thymine and guanine). Electronic signals in the brain pass along neuron filaments and across synapses, but not in digital binary form. There is no evidence whatever of any form of a Morse like code either in DNA or neurons. The principle difference is that neural messages can vary in amplitude. The smallest unit of information can have a second dimension: not just presence or absence but also volume. We do not know if the action potentials along the dendrites and axons vary greatly, but we do know that it is not just a matter of whether a signal is, or is not, transmitted across the synaptic gaps. The effectiveness of that signal can vary either according to the current volume of neurotransmitters output, or the ambient hormonal state the synapse is bathed in, or, possibly, by the width of the gap which may vary according to state of tension across that synapse, or, most likely, any combination of all three. Similarly the neuron nuclei respond by activating their axons according to the volume of stimulation received from one or more of their dendrites. Information in the brain is almost completely 'analogue'.

An analogue message is sent by the strength of the signal. A digital message in telecommunications and computers is sent by converting that 'strength' to a value and transmitting the binary equivalent of that number. Motor neurons activate the muscles that enable us to move by the volume and frequency of their signals. The electronics of robots tend to be designed to send digital signals to move the robot's limbs, for instance, because the movements to move the motors can be more precise. Robots process digital or 'artificial' information and their programs are said to have 'artificial' intelligence.

***Biological information in the brain can be defined*** *as patterns of electrochemical neural activity that can induce sensations perceptions & emotions; muscle activity and stimulate other neurons, glands and all the other organs in the body.*

Information that is being transmitted from the sensory organs to the brain and between the brain and the muscles and other neurons and organs can be *defined as* '***kinetic information'*** – it does work. Kinetic information generates the growth of new stable neural structures temporarily, or permanently that can reflect this pattern of activity in such a form that, if stimulated at some future occasion, they can reproduce a similar pattern of neural activity. These structures or 'memories' can be accurately *defined as* ***'potential information'.*** So we can add to the definition of memories that they are structures that encapsulate potential information**.**

***Biological information can also be defined*** *from another perspective as the embodiment of how we interact with the world. One type of information is a representation of the external world and another is a representation of our bodies, sensations and feelings.*
Thus we have the means to compare the one with the other and monitor our behaviour.

*It can also be argued that much of human information is the theories we construct of our understanding of the universe. Theories are abstract, and are the logical extension of words.*

These are useful additions but the form of these representations is still electrochemical physical neural activity.

By its nature electrical activity is transitory. Electrical activity can only be held stationary in some form of structure like a battery. Thus we can argue that 'memories' have evolved to act like 'information batteries' to store neural activity so that present experience can be called upon in the future. We can also borrow the analogy of a 'file'. This storage creation process is what we call '***learning***'. There are other examples of this phenomenon. Neurons are hosts to mitochondria that steadily convert nutrients into adenosine triphosphate (ATP), which is a form of energy store or 'biological battery'. In turn ATP can be converted on demand into action potentials to transmit signals along the axons and dendrites.

We need to define electrochemical physical neural structures and streams of patterns of electrochemical physical neural activities.

***Electrochemical physical neural structures can be defined*** *as the physical neurons, of which there are many different types, each consisting of a* nucleus *with* dendrites *that input information and feed back in the form of electric signals generated by the sensory and other organs and other neurons; and* axons *that that output information to the muscles, glands and other organs and neurons in the form of electric signals. The dendrites receive signals and the axons transmit signals across connections that consist of clefts or gaps known as synapses.*

The nucleus contains varying numbers of mitochondria that convert nutrients to energy. Signals are carried across the synaptic clefts by a variety of neurotransmitters. A range of hormones and messenger molecules can bind to dendrites and axons to vary their operation and in particular the amount of neurotransmitters output at the synapses. The synaptic structures are strengthened by usage, and can be moved along receiving dendrites or muscles to fine tune the timing of instructions. The structures of the dendrites and axons are strengthened and insulated by coatings of myelin to increase the efficiency of their signalling. Electrical messages are transmitted along the dendrites and axons by the interaction of sodium and calcium atoms which 'leapfrog' along these filaments generating 'action potentials'. There is a large array of glia cells that carry out various functions, including providing temporary links between neurons, channelling nutrients from the blood stream to the neuron nuclei and disposing of neural debris. A physical neural structure capable of transmitting neural signals can be a loose temporary string of glia cells to a mature complex neuron network of well established myelinated neurons with many powerful synapses capable of complex reactions and potent output signals.

***Patterns of electrochemical physical neural activities can be defined as*** *the stream of electrical signals transmitted across the neural networks typically from the sensory and other organs to the brain; and from the neural networks in the brain to the muscles and other organs; and between the neuron networks.*

Neurons send outgoing signals along their axons in response to incoming signals from their dendrites. A neuron may respond to a single dendrite message or only as a result of a build-up of incoming signals. Weak signals may me amplified by a positive ambient hormonal state and strong signals ignored in a negative hormonal state. Signals transmitted along axons may be varied by the activity of the mitochondria and the level and volume of ATP. The strength of the signal along the dendrites and axons varies according to the prior usage of that neural structure, whether it is recent and only just formed, or robust and myelinated. The amplitude of the signal transmitted across the synapses can vary according to the strength of the basic signal, modulated by any messenger molecules attached to the axon, the volume of neurotransmitters available to convey the signal across the synaptic cleft and the width of the synaptic gap. Once a synapses has fired, further activity is temporarily inhibited. This appears to be a way of mitigating background 'noise', and confusion arising from repeated signals, although the downside may affect recall, of which more later. Separately synapses can be permanently closed to circumvent recall of unwanted signals.

Although nuclei appear to be able to vary the amplitude and frequency of signals transmitted, there is no evidence to suggest that nuclei can send codes in any sense like Morse code. Systems thinking suggests that nuclei may be able to selectively direct signals to different axons. This conjecture supports the hypothesis that individual neurons can participate in multiple networks and structures. For instance: neural networks representing words have axon connections both to the speech systems and the writing systems. It may be the nuclei have the means to selectively activate only one of these systems. Observably individual words can be part of many memory systems.

We can use these analogies and descriptions to help us define

## 1. A More Comprehensive Definition of Biological Memory.

*Biological memories are electrochemical physical neural structures that develop in the brain and act as a form of 'neurological information battery, or file'. These configurations can encapsulate and store streams of patterns of electrochemical neural activities which are able to induce sensations, and neural signals directly or indirectly activating muscles, glands or other neurons temporarily or permanently. On demand, when these configurations are recalled or stimulated, they can induce a repetition of the original stream of patterns of electrochemical neural activity as often as required. These neurological structures persist over time and can be strengthened, amended, updated and extended. Biological memories encapsulate 'potential information'. When biological memories are stimulated and reproduce a stream of patterns of electrochemical neural activities they generate 'kinetic information', which can do work.*

Biological memories, therefore, can be described as neurological stores capable of inducing algorithms of patterns of neural activity. Conceptually they bear a strong resemblance to the subroutines that make up the programs of software systems. The great strength of these algorithmic structures is that they can be used together in ever more complex hierarchies to build ever more complex systems. Thus one neurological algorithm (memory) of a 'word' can activate a mass of connections that stimulate sensations which we experience as 'meaning'; another the pattern of neural instructions to speak that word, another to move the finger muscles to write it; whereas other neurological algorithms can include that 'word' in strings to recite poems, for instance.

***A 'sound bite' definition of neural memory is a pattern of neural instructions.***

> Note: The smallest measureable unit of energy (light) is a photon. There is a clear and present link between energy and information. Photons appear to behave both as particles and waves. When we observe waves they are active (kinetic). When we observe particles, they are stationary (potential). Perhaps waves are energy and particles are information.
>
> Note: Observation suggests that information requires a carrier, and can only be stored in physical systems.
>
> Note: Information is necessary to provide energy with order, which is a prerequisite of structure and symmetry, which, in turn, is perhaps the basis of beauty.

## 2. The Formation of a Memory of Information

Biological memories are formed – 'grown' as an automatic response to patterns of electrochemical neural activity generated by surrounding neural structures processing signals (1) from the sensory organs registering external activity, (2) from internal organs registering activities in the body and (3) by the activity of other neurons. [the Hebb principle: Neurons that fire together, wire together].

The strength of these temporary speculative memory patterns depends on the strength of the input signals and the ambient hormonal state. If no further input activity accesses these provisional memory structures they may dissolve. However, every time these structures are activated they are strengthened and so, in due course, grow into increasingly robust long term permanent structures.

## 3. The Recognition of Information.

Recognition and recall of information are often conflated but they are very different processes. Recognition is predominantly about identifying information arriving in the brain from the sensory organs: from the outside. Recall is about finding information, rather as one might access an encyclopaedia: a query from inside.

Recognition can be described as the neural process where stimulations that are recorded by the sense organs generate a pattern of neural activity that flows along the neuron paths laid down by previous similar experiences thus energising a similar response. The event is *re-cognised*.

New or variant sensations generate new or variant pathways through the neurons. When a new pattern varies from an existing pattern the neurons create new links opening a new pathway. Thus all new information builds on all existing information step by step. The implication of this is that neural patterns that represent information are not profiles that can be matched to existing profiles, but are routers that navigate the mass of paths through the neurons. At no point does an incoming neural pattern of a sense stimulus reach a neural 'memory'. The incoming message finds its way through the mass of distributing neurons to the point where it begins to stimulate neurons connected to muscles energising a response. From one point of view we do not have memories in the sense that a computer stores passive information on various types of memory media, or a dictionary stores words, or an encyclopaedia stores facts in words and pictures. In effect, memory emerges from sets of instructions as they develop.

At birth all the organs of the body are connected to the brain. For example the ears are able to hear noises by converting the sound waves hitting the ear drums into neural signals which pass to the brain. Similarly the brain is connected to the muscles that control the lungs, vocal chords and the movement of the mouth, lips and tongue. Thus babies can hear and make noises. However, at birth babies can not differentiate between different sounds: for instance they can neither hear nor speak one single word. The same applies to the other four senses and internal organs.

Different sound patterns cause alternative neural structures to form between the ears and the brain. Variant neural structures grow between the brain and the vocal system to cause different sounds to be made. Very slowly to start with, but with increasing skill, babies imitate the sounds they hear and they try and make similar sounds by continuous repetition and experimentation, and, in the process align neural structures from the ears and through the brain out to the 'speech' muscles. Each time a word is repeated that neural structure is strengthened. Each time a new sound pattern, or word is heard it generates a variant neural structure into the brain and out to the speaking muscles. Thus each baby 'grows' a vocabulary.

We have a single source – the ears, and a single speech system. In between we grow a mass of distributary neural networks from the eardrums into the brain connected to a mass of networks concentrated into the speech system muscles. Learning to read involved growing a second set of distributary networks from the eyes. As we learn to write we grow another mass of neural networks concentrated into the muscles of the fingers to manipulate pens, keyboards and the like.

As a baby learns to associate sound patterns with other media input: a face, a smell, a taste, a feel, so neural structures grow to mirror these relationships. Thus 'seeing' mother's face stimulates the neural structures to speak the sound 'mother'.

Incoming information flows along the neural paths that have been formed by the previous receipt of similar information, leading to and stimulating previous experiences associated with that information. Thus the neural structure of the 'memory' of a word starts as close to the eardrums as the neurons start to differentiate that distinctive sound, then spreads out in ever increasing complexity. One 'output' of this mega network is concentrated into the speech system another into the 'writing' system and so on. A number of observations support this definition. One is that this explains how the system recognises different meaning for one word. For example 'Berlin' can be a name or a city according to context. This process sets the 'neural points' according to the previous words, thus if the context is music the word 'Berlin' following Isaiah will be recognised as a surname with no connection whatever to geography. Another example is the ability to identify incomplete information. For example, the waving of grass may indicate an approaching predator. This tell-tale pattern of input from the eyes can be identified very quickly and the signal will short cut more detailed networks to activate a neural alarm.

***The definition of the ability of the brain to recognise information*** *is the process whereby incoming information signals travel along the neural pathways most similar to those grown as a result of comparable previous experiences and thereby stimulate earlier memories, which either respond according to the stored patterns of activity or register differences according to the nature of the new information, and the context.*

## 4. The recall of a memory

We can observe that there are wide ranges of ways in which we need to recall information. We need to know how to react in a crisis. We need to recall information like someone's name, or an important telephone number, or some facts to answer a question. We need to recall the meaning of a word or how to spell it. This list is endless but they all divide into broadly two categories; - determining what action to take; - answering a question, which is often an abstract concept.

Over millions of generations, evolution has selected for the fastest possible reaction to potential danger, food or the presence of a mate. Recalling and activating these memories is often stimulated from information flowing in from the sensory organs, and usually involves causing the motor neurons to move our body. The larger volume of interrogations come from other neural activity and often involves a string of words.

Neural memories can only be accessed and activated by neurons stimulating the potential information into kinetic information that can carry out a function – do work. The conversion of potential information into kinetic information requires energy thus we can say that the definition of the successful recall of memorised information involves both the locating of that memory structure and, crucially, that structure having the ability to deploy sufficient energy to generate a pattern of neural activity strong enough to make an impact in a brain teeming with activity. Both criteria need to be satisfied for a memory to be satisfactorily recalled.

Just as the ambient hormonal situation and the strengths of the signals plays a significant role in the formation of memory structures so the ambient hormonal situation and the strengths of the searching signals is crucial to recalling, finding and activating memory structures. Most memory structures have many cross referencing links, therefore, in reverse this cross referenced information can play a part in locating a memory. The memory structure may be so well established and so often accessed that the memory structure itself is very powerful.

***We can define the ability of the brain to recall information*** *as the process of accessing recorded previous experiences and causing the identified electrochemical neural patterns to generate sufficient energy to transmit a set of instructions, or initiate other neural activity, according to the nature of the interrogation and the information found.*

We can observe that we sometimes are certain of a correct answer, sometimes unsure. It seems likely that the level of certainty is related to the strength or otherwise of the signal generated which might be a result of multiple accesses or the strength of the enquiry or the intrinsic strength of the memory structure.

***We can define the failure to recall information*** *as either an inability to locate the memory structure, or an inability of that memory structure to generate sufficient energy to transmit a pattern of signals strong enough for the brain to recognise.*

Much research has gone into the former, practically none into the latter. Younger people and older people face different circumstances in both forming memories and recalling them. Younger people have far less information to access and through lack of experience the available information has far less contextual cross referencing to assist in recall. Older people have the opposite problem that they have vast stores of their lifetime's experiences to sift through.

As noted above, when messages are transmitted across a synapse the immediate effect of this activity is to cause the synapse to relax while it 'recharges' its capacity. From a systems point of view this has the advantage that message processing is not confused by 'noise' and repetitive information activity. However, if an otherwise successful retrieval only generates a weak response, then not only does the primary signal pattern not get recognised, but there is no follow up. This would explain why, when we fail to retrieve some fact or word, it remains inaccessible to us for a period of time. Rather than panic a better strategy is to relax, whereupon the fact or word is often retrieved once the synapse has recovered.

> Note: Nothing like enough attention has been given to the volume of energy that is available to the brain. It is slowly being realised that diet and reliable food supplies have a major impact on young people's ability to learn – both to concentrate and to form - grow new neural structures. Observation suggests that in later life memory tends to begin to fade gradually. Many older people report that while they are sure they know the answer to a question, it seems to be just out of reach, or is "on the tip of their tongue". Answers often surface at a later date. Well known facts, particularly individual words, are temporarily lost. These observations suggest that the problem of progressive inability to recall information may well be due to insufficient energy being generated by the activated memory. This could well be a problem of diet, but equally it could be failures in the nutrient path to the neurons, or, of course, a combination of both. Research into this aspect of memory could both identify ways of combating these types of problem and shed valuable light on these aspects of the operation of the brain.

## 5. The Meaning of Information. [& knowledge encapsulated in Memories].

A very simple 'soundbite' definition of the 'Meaning of something' is the effect it has on us.

The nervous system evolved to connect up all the organs of the body to operate as one coordinated, cohesive, cooperative whole. The sensory organs provided information about the external world to enable the organism to navigate its environment and respond to events. At this level 'meaning' is straightforward. Monitoring the outside world and registering a predator generated a sensation of fear and stimulated a response to escape. Internal neural signals registering hunger stimulated a hunt for food. Language interposed an interface between this simple cause and effect. The shouted warning was as efficient as visually witnessing danger and offered far greater precision and longer time to react.

Language made it possible to think about abstract ideas. Thus it became possible to be frightened, or elated, by an abstract idea. The reaction might not be a physical action – running away: it might be a verbal riposte. Meaning, therefore, evolves with language.

An electrochemical physical pattern of information flowing through the neural networks can come from the internal organs, from the sensory organs registering external events, or from purely neural activity. It is one thing to be able to respond to what is going on, but it is quite another to understand the more subtle aspects of the meaning of what the neural networks are transmitting.

Information divides into four categories:-

1. Facts. Shapes, sizes, colours, attributes, orientation, direction.
2. Relationships, associations, cross references, affiliations, and categories.
3. Implications.
4. Extrapolations.

## 1. Factual Information.

It is an easy first step to see how advanced fauna could learn to associate various sense experiences together. Fruit and food; smell a predator and run; sound, a waterfall and a drink, and so forth. Increasingly specialised sounds enabled differentiation between various different sense experiences. Different sounds for different foods. Variant sounds to warn of different predators. Gradually we developed one class of words to label things, which in due course became nouns; and another class of words for actions which in due course became verbs. This gave our ancestors a means of referring to things and actions by sounds that were accepted by the tribe and passed on to each generation. What each proto word sounded like was irrelevant so long as the group all attached the same meaning to them –reacted in the same way. All these early proto words shared one common factor; they all directly connected senses and other organs to muscles or other organs. Their meaning was anchored to the five senses and the effects were anchored to muscle action and the stimulation of glands. Recognising a predator stimulated the adrenal glands. Words generated emotions. The lineal descendents of these sounds are music, song and poetry.

The growing ability to hear and make a growing repertoire of much more sophisticated sounds created completely new capabilities. This expanding vocabulary stimulated a substantial expansion of the neural networks differentiating all the new words, paralleled by more sophisticated neural networks to control of the lungs, vocal chords, throat, mouth, tongue and lips to articulate them. The direct links to the emotions weakened as the associations of words with other sense information became more significant.

Then an apparently small and modest innovation opened a Pandora's Box of possibilities. Our ancestors developed words that did not match any thing or action: words that were abstract and therefore purely neural. Maybe they came about as a way of defining and differentiating existing words more accurately: adjectives and adverbs.

It is easy to see how neural patterns – words – can have a meaning where they act as labels for artefacts that can be seen, heard, smelt, tasted and felt or for actions that can be carried out. However, these new abstract words have no such anchors. They are in suspended animation. Thus patterns of neurons acquired a meaning all on their own. They could only be interpreted or understood by their association with, and reference to, other words.

Words as labels or actions are in the world. Abstract words are in the head. This seemingly modest development caused a new kind of neuron to evolve: neurons that were solely connected to neurons and which provided a series of variants to existing neural word structures. Furthermore, the same abstract word was not only linked to one other word. It could be applied to many existing words, so it had a meaning of its own independent of any word it modified. Adjectives like 'big' and adverbs like 'fast' acquired meanings unconnected to artefacts and actions. These neural constructions could only have meaning by convention which had to be passed from one generation to the next, and this could only be done by reference to language.

The potential change to the fundamental structure of the neurons was immense and involved linking two quite separate neural structures together. The neural pattern to speak a word like 'big' was not connected to every artefact but held separately. Thus the capacity evolved to link these two words together to say them; and similarly the capacity evolved to hear a word pair like 'big tree' and interpret the two words separately, but link them together to understand how the 'meaning' of one modified the meaning of the other.

## 2. Relationships, associations, cross references, affiliations, and categories.

Thus it became possible to link together two quite separate neural patterns in combination to extend the meaning of both. When the ears hear, for instance, the two words 'big' and 'tree' their neural patterns will follow different paths. Subsequently these two patterns will have to be associated again so that the meaning of 'tree' can be modified by the observation that it is a 'big' tree. Similarly to convey the fact that the tree is big, the neural patterns of 'tree' and 'big' have to be assembled in the correct order, possibly from different parts of the brain, and the appropriate muscles activated to say both words.

This is an enormous step forward in the evolution of the brain, and suggests the beginnings of a hierarchy of patterns and the emergence of some meta neurons that have the ability to assemble one or more lower order neural patterns into more complex higher order patterns: what we call categories. This process of assembly is not physical: there is no suggestion that neural patterns are transported around the brain. [That is the way computers are programmed but the brain has no facility to do this] It is more likely that the component neural patterns are connected by the growth of temporary neural structures and links. This is a similar process to the way in which sense images are temporarily linked together to form the panorama of the world that enables individuals to be consciously awareness of their surroundings – the sensation associated with being awake.

These facilities proved to be expandable in a number of ways. The gradual expansion of the vocabulary enabled many pairings and groupings. As well as adverbs and adjectives there are all the relationships, associations, cross references, affiliations, and categories. Thus the stimulation of the neural networks representing one word in turn stimulated many other word networks, in addition to being mapped onto the representation of other senses, emotional responses and all the words associated with these. Thus the evolution of words expanded simple one to one object response links into a mass of ever more sophisticated networks of connections. This caused a rebalancing of the brain. For a very long time the brain was largely concerned with processing visual information. Progressively, making, hearing and cross referencing words, doubled the size of the brain. Then writing and reading word images took this trend further. The creation of new words- the majority of which are abstract- are growing exponentially and the modern brain copes by building ever more neural links and structures.

Thus 'meaning' is related to complexity. Complexity does not create meaning *per se*, but complexity provides the means and process to add depth, intensity and vigour to meaning.

## 3. Implications

The next big step was to enable the descriptions of actions to be linked to artefacts: "get fruit": "drink water", and so forth. This, in turn, opened the way to string numbers of words together to form phrases, clauses and sentences whose meaning was greater than the sum of the constituent words. This generated another important breakthrough. Not only could words be strung together to enhance their meaning and therefore enable the speaker to increase the chances of the hearer understanding the message the speaker was trying to convey, but it also introduced the concept that certain combinations of words were inadmissible, such as "drink fruit".

It opened the way for groups of words to be linked together and indexed by a new word. A good example is the word 'impressionist' which immediately conjures up a group of artists, the style they painted in and a host of other associated information. Mentioning this one word to another individual stimulates a similar mass of neural structures in the hearer.

## 4. Extrapolation

Language opened up the forth dimension – time. People could reminisce to each other about events in the past, and speculate about the future. For the first time life forms could escape from the hugely limiting weakness of all selfortems - self organising systems, which have no means of forecasting the future. Human beings could extrapolate their speculations into the future and, therefore, make preparations for possible eventualities and make provision for future events. They could begin to influence these events and modify their environment, which is not only a major part of conscious behaviour but also a principal contributor to the development of civilisation. They could preserve some of this year's harvest against the risk of famine in the future. It became possible to ask questions and for individuals to interrogate each other. "I did not understand that, please explain it again". Individuals could comment on some phenomenon and speculate how it happened and what caused it to occur: the beginning of thinking.

Combining words was paralleled by an expansion of words, which, like adverbs and adjectives were abstract. People could both define, talk about and therefore think about ideas and concepts. People could ponder on the three great questions. "Where do we come from? Why are we here and where do we go?" Our community has made remarkably little progress on answering any of these questions! However, they opened up the possibility to debate behaviour, right and wrong, morality and ethics. Thus early communities could establish rules to help them to live together harmoniously and cooperate more efficiently and so the concept of law was created.

The ability to string words together and build meta patterns suggests a degree of control, or at least initiation. Thus human beings learned to take control of their propensity to dream and build it in to the quite extraordinary and apparently unique ability to imagine. Imagination makes it possible to speculate about the future course of events in a very constructive way. To be able to imagine what might happen 'if' certain events developed, and what might happen 'if' one course of action was followed as opposed to others is, perhaps the most powerful weapon in the human intellectual armoury. It is only possible to imagine in a state of consciousness, and the ability to imagine means it is possible to do at least two things concurrently. It is possible to live in the existing world and at the some time disappear into a fantastical imaginary world. The computer world would call this parallel processing. It suggests a very sophisticated operating system that is capable of interrupting the processing procedures and developing hierarchies of priorities. In neural terms it suggests further layers of ever more sophisticated neurons that can prioritise the activities of masses of neural networks almost as though they were in competition with other masses of neural activity. On top of such a pyramid of abilities must be neuron structures that enable each individual to direct the activities of other neurons.

However, we have travelled rather fast along the evolutionary path. We need to go back and look more closely at the how a mass on neurons in the brain understands the meaning of words, combinations of words and how it is possible to work out the implications of their meaning, and then go on to extrapolate their meaning to solve other seemingly unconnected conundrums. If, and when this can be understand we will have a much firmer grasp of what we recognise as our conscious understanding of ourselves, our universe and our place in that universe. Hopefully, the definitions of how these processes operate will enable us to better understand what underlies the learning of new skills and thinking.

The initial components are the evolution of words as labels; then words for abstract concepts and ideas; then the ability to link words together to form patterns and the ability to link patterns together to make meta patterns with, perhaps, single new words acting as indexes to those meta patters followed by a hierarchy of these patterns building up into ever more complex grammatical structures.

Mapping the neural patterns to hear and say words onto the representation of information coming directly from the senses appears to be straightforward. However, almost everything seen by the eyes is part of a group, or category. For instance there are many types of trees. These arguments equally apply to all the senses, but using sight is the easiest to describe. Immediately there is the problem of the association of ash, beech all the way down the alphabet to willow, which in many ways all look quite different, but are nevertheless equally recognisable as trees. Then there are all the other attributes of trees like leaves, bark, reproduction habitat, diseases and uses of their timber…. The list goes on and on. One possibility is that the neural representation of words like oak and elm are cross referenced by axon and dendrite links to words (and their sense representations) like trees, leaves and so forth. The brain may grow a trillion new neural links in a life time, but even this immense number would not be nearly enough to provide links from everything to everything, and the result would be so unwieldy, ever slower and increasingly inefficient. It is more likely that the neural patterns for all the members of each grouping are connected to one meta pattern for that category. Thus 'trees' becomes a logical or category generalisation which, over time and usage, develops its own neural patterns that have agreed and defined boundaries and defined combinations and relationships that are acceptable and excluded. Thus, for example, ‘trees’ includes bonsai, but excludes bushes. Thus the word ‘tree’ is not associated with any one any specific image, but with many images of specific types of trees. In neural terms this is very efficient because whether a representation – memory – is being accessed or added to there is always only a one to one link either from ‘oak’ to ‘trees’ of from ‘tree’ to ‘beech’.

We can use the word ‘icon’ to describe the way we use words and concepts like ‘tree’. Icons represent attributes and experiences and the relationships between associated members in that category. They also define limits. Trees produce seeds, but trees can not walk or move about. We can deduce knowledge from these limitations. All the members of this category can be a source of food; and they will always be in the same place if we wish to find them again. This meta information needs only be represented neurally once and not wastefully repeated for each constituent, similarly it is only necessary to update the knowledge bank of trees for some new discovery, and not the knowledge bank of every individual tree.

Thus iconic words like ‘tree’ have a meaning in the context of all the other words and phrases. The reference and meaning of such words is distributed amongst all the words involved. When a person hears such a word all the relevant sensual information associated with all the members of that category are alerted – all the multi media representations of oaks, cedars etc. All the associated information is available, which cumulatively contributes to a sense of understanding, provides the basis for any reaction or associated activity, provides the raw material to appreciate any implications, and further provides the foundation to extrapolate this information to establish or add to a higher order neural pattern or create links to existing category patterns.

Trees are part of the whole natural plant world. Trees are constituents of rainforests, they are similar but different to bushes. Neurally this creates another level in the hierarchy of neural patterns. At this level it is possible to develop relationships between groups. Similar rules for inclusion and exclusion apply but on a much broader basis. Thus all the information known about trees can be compared with all the known information about bushes without having to think about a single type of tree or a single type of bush, yet the outcome of such contemplation will apply to every tree and every bush.

We can use the word ‘index’ to describe these meta patterns of icons. These meta patterns enable icons to point to, or indicate other icons and establish accepted relationships.

We can go one step further. All the examples to date are grounded in one to one object relationships: the word oak and all the multimedia representations of oaks. There are visual images of trees. There are visual images of rainforests, plants and so forth. However, concepts have evolved that have no such direct representation. No one has seen, heard, smelled, tasted or felt a ‘home’. Words like ‘home’ are symbolic. They are the manifestation of a concept. They are both the sum total of all their constituent parts yet they are more than that. They are an impression, a feeling, a sensation. A multitude of individual objects contribute to a home, many iconic groups of things and attributes contribute to a home. There are many groups of groups, but the concept of a home has a life of its own which can stir the deepest emotional responses. This concept of ‘a life of its own’ independent of its constituent parts is itself a symbolic representation of a series of concepts. They are represented in the brain by their own neural networks that are grown as a result of thinking about the underlying concepts. They are grown as connectors to all the networks that contribute to their conception, level by level right back to the initial one to one representation of an artefact or action matched to a word. Nevertheless, such symbolic concepts exist only in the neurons; however they have very strong meanings and very powerful influences over behaviour.

As the human brain evolved, the ability to associate patterns together from the direct mapping of words to objects, all the way up to symbolic conceptual representations, it seems likely that more sophisticated neurons, perhaps with many more axons, dendrites and synaptic links evolved to carry out these tasks. This suggests that the pressure to acquire and understand the meaning of knowledge was equally responsible for the evolution of the brain as the evolution of the brain facilitated the ability to acquire knowledge. At the very least the development was symbiotic.

This structure of hierarchies of nested neural networks has many implications.

It would seem that the creation of meta patterns is a sophisticated extrusion of the basic neural ability to recognise, respond to and emulate statistical regularities (sometimes described as 'pattern invariance'). Higher order patterns are stimulated every time lower order patterns that conform to a category are accessed. Over time, lower order pattern activity becomes so ubiquitous that is drops into the subconscious, or 'autopilot' mode: the conscious activity fades across the boundary of consciousness. Similarly relationships fade into redundancy below the conscious horizon. The neural networks are still in place and active but they no longer operate within the conscious domain. Thus the sensation of knowledge, meaning and understanding all are present. Only if it is necessary to investigate why a person holds a particular belief, is it possible to activate these underlying lower order patterns. Hence it is often difficult for people un-learn something as these underlying lower order patterns have to consciously activated and then amended: not always an easy task. For example, people who were brought up before the adoption of metric and centigrade, can sense the length of a yard but not a meter. They are more comfortable with the number of miles their car can do to the gallon. They know exactly what the sensation of $80^{o}$ F feels like, while $27^{o}C$ does not have any meaning to them.

Learning is all about discovering relationships, linking something new to something already known. For instance, it is much easier to learn about a new tree if a lot is known about trees already. It is only necessary to slot in the new species at the lowest level and the structures already in place provide further information. This demonstrates the great importance of learning some new subject by first establishing the outline structure into which increasing levels of detail can be slotted. Establishing the meta pattern then adding in lower order detail appears to be reversing the natural order for the acquisition of knowledge. However, this is just a manifestation of how greater knowledge of how the brain operates can help us improve the whole process of teaching, learning and education. Higher order meta structures can be established in many subjects by first studying the purpose of learning this subject. Once the framework is in place it is progressively easier to work through how these objectives can be answered.

The more symbols in place the easier it is to create more. Conversely it is difficult to relate symbols until some are in place. A chicken and egg problem. Hence it is much easier for adults to learn new subject than it is for teenagers. Similarly, adults are more likely to appreciate the implications of some new piece of knowledge and be able to extrapolate knowledge of one subject to expand their understanding of another. Equally and oppositely young people often come up with more novel solutions to problems than adults, because the have not been taught the ‘correct’ answer – the current accepted wisdom. Adults have in place structures that generate the learned response to some situation and quite often that solution becomes apparent without conscious effort, so it is not apparent to that person that their answer could, should or can be queried.

The greater the variety of structures that can be assembled to establish some new relationship or pattern the more effective the new knowledge, hence the value of multi media input from as many sources as possible. This also explains why it is easier to understand something from a second source especially if the second source approaches the subject from a different perspective, style or structure. The part constructed pattern is completed and made more robust with the new input from the different source.

A great deal of this processing happens automatically as more about the subject is discovered. If a person is learning something that is of great interest to them this process will be easy and efficient. If that person is learning something of little interest perhaps only part of that person’s attention is in play and so the stimulus to establish a meta pattern is weak. What we can observe is that meta patterns are built on existing knowledge structures. If one group of people are growing pattern structures in a different way to others their experiences will be different and they will frequently draw different conclusions from the addition of similar information. Similarly, people learn with different goals. The obvious example is where people are learning something in a particular way to answer certain types of questions, for instance, for the purpose of satisfying the format and structure of a set of questions like an examination. It follows that the meta pattern structures of, say, one group of students learning something for their own edification will be different, possibly substantially different, to another group of students concerned with passing an examination. The two groups may well have a quite different understanding of the implications from their activities.

These masses of hierarchical neural patterns are not region specific in the brain as they link so much together. This geographical spread is already surprising the researchers who are studying brain activity related to various stimuli. As meta patterns are developed so individual items of knowledge are less position specific. This makes knowledge increasingly robust, as the volume of cross referencing is ever increasing and there is huge overlap. Any one item can be accessed from many different levels facilitating recall. Similarly any neuron wear or damage is less serious as alternative means of access to specific neural structures are available while replacement networks can be grown

The facility to recognise and neurally replicate statistical regularities helps identify new rules of combination of lower order neural patterns into higher order structures. Such rules are inclusive and exclusive, and from these structures have grown syntax, semantics and grammar. It is also the process by which the patterns of behaviour of people have been worked out, rules devised and the laws of behaviour among the members of communities developed. It is the same process whereby the statistical regularities we observe in the universe are promulgated into what we call the ‘laws’ of nature and the ‘laws’ of physics.

We observed earlier that when words started to evolve, sound processing in the brain divided into two paths with words developing independently from music. However, music is also attractive to us because of the structure of patterns it creates. Tunes are patterns that can be recognised and so found both striking and familiar. The process of recognition directly stimulates the glands so, often immediately, changing mood, sometimes dramatically. Laughter is often generated because an expected pattern is interrupted generating sudden surprise. Poetry and song overlap the domains of words and music. Rhyme, rhythm, metre, onomatopoeia and alliteration enable strings of words to convey meaning substantially greater than the sum of the individual words. They convey such ephemeral impressions as beauty and attraction by stimulating emotional responses that add so much to the understanding and meaning of things, which otherwise are so difficult to describe, define and measure, and which are often classified as qualia.

## Space, Time & Orientation.

An analysis of meaning would not be complete without addressing space, time and orientation. Long before the beginnings of speech and language humans shared another dimension of meaning with other living forms – mammals and possibly others. We know that when the senses register an event a considerable amount of processing takes place as this information enters the brain and alerts the representations of similar events in the past. Thanks in part to two ears it is possible to identify from which direction a sound comes from. Having two eyes helps indicate the distance away some object is and its position and direction of movement relevant to other objects. The brain has a sense of the sequence of events in the procession of time. Animals, like the insects and birds, have a sense of orientation. They can all find their way to their nests, while many species migrate over immense distances. Bees can describe to other bees where to go to find honey. These are all essential contributors to our understanding of events happening in the context of the surrounding world. Words have multiplied these latent skills because it is possible to describe them and so help people to make the most use of their latent talent. Similarly human beings have a sense of harmony and balance. To a limited extent we can describe these attributes in words, not so well as to be able to define them, but well enough to teach people how to recognise and develop their own latent abilities. Thus meaning includes concepts of direction and orientation.

Another important component is the ability to imagine. It is possible to engage the full range of our attributes into imagination. Imagination encompasses all the emotions: space and also time; but above all imagination is dependent on words- the whole massive vocabulary. Without words imagination would probably still exist, if in a much reduced form, but it would not be possible to communicate imaginings and so they would lose a large part of their influence. Imagination makes it possible to experiment with alternative meanings. Words give imaginations meaning, and, in turn, the ability to imagine greatly supplements the ability to understand the meaning of everything that happens.

We noted that the ability to associate seeing fruit to recognising food, and hearing water to recognise a source of water to drink, contributed to the beginnings of consciousness. Being able to understand the meaning and implications of what our senses register, through the medium of language, and then go on to be able to extrapolate one set of solutions and map them on to another set of problems and so invent some new solutions, has expanded the boundaries of conscious awareness onto the plane where we find ourselves today. It is not going too far to say that without this sense of meaning, understanding, implication and extrapolation we would have very little conscious awareness. We would be not much more that ambulatory computers. The ever richer panoply of words and their meaning is an index of our level of consciousness. Given that we believe we are significantly more conscious than our distant ancestors, then it follows that we could be even more conscious if we discovered or invented how to learn to be more conscious. We can do this by experiment, debate and observation, and so expand the horizons of our understanding.

***The Definition of the Meaning of Information** begins with the simple sensations generated by patterns of neural activity to the reaction to simple stimulations coupled with previous experiences and their outcome. At the next level meaning is extended by the relationship to other emotional sensations: other media: Taste to smell: vision to sound; and includes a sense of balance, direction and orientation; and also purpose, objective and value.*

*Language adds multiple dimensions. The meaning of a word can be defined in terms of other words i.e. all the other associated words stimulated. Meaning can now be defined much more accurately, but often in terms of other words: multiple words generate multiple sensations adding depth and complexity to sensations. Words also stimulate the sensations in subtle ways. Rhyme, rhythm, metre, onomatopoeia and alliteration enable strings of words to convey meaning substantially greater than the sum of the individual words. They convey such ephemeral impressions as beauty and attraction by stimulating emotional responses that add so much to the understanding and meaning of things, which otherwise are so difficult to describe, define and measure just in words, and which are often classified as qualia.*

*The meaning of more complex information is bound up with the ability of the brain to identify statistical regularities. So, finally, the meaning of information is also contained in the meta patterns it encloses and stimulates.*

Notes

1. **Definition of a computer**.
   Computers are electronic machines that can store, process and analyse machine (artificial) information using hierarchies of rule based algorithms, or programs, to construct ever more complex and sophisticated systems of artificial (or machine) intelligence.

2. **Writing**
   Converts spoken words (ephemeral sounds) and ideas (neural activity) [kinetic information] into permanent, fixed visual images (memory) [potential information].

3. **Reading**
   Converts permanent, fixed visual images (memory) [potential information] into ephemeral sounds (spoken words) and ideas (neural activity) [kinetic information].

4. **Information**

   Information (knowledge) is potential energy. Knowledge can be stored and recalled. Knowledge is of no use on its own unless it can be converted into kinetic energy: do work. [data on a computer medium is valueless without a processor to read it].

The sounds of language (speech) and neural activity stimulated by the sensory and other organs (thinking) is kinetic energy and can do work and be processed. Neural activity stimulated by the sensory and other organs (thinking) is kinetic energy and can do work by:-

4.1. Stimulating motor, glandular and other neurons to execute activities (conditioned reflexes).
4.2. Generate the formation of temporary speculative neural links and structures (glia bridges) which is a basic form of potential energy and a building block of temporary memory.
4.3. Strengthen existing neural links and structures (axons, dendrites, synaptic links, and myelation) which are a stable form of potential energy and building blocks of permanent memory (potential information).
4.4. x

Neural activity can stimulate motor, glandular and other neural structures to execute activities and so convert potential information into kinetic information.

## Definitions

1. Words are indexes and descriptors of things and actions [nouns & verbs]
2. Moderators of other words [adjectives & adverbs]
3. Symbols of abstract, ideas, concepts & thoughts.
4. Connectors to other words
5. Words are the building blocks of Language
6. Words are carriers and agents of meaning.
7. Strings of words (phrases) multiply the meanings of individual words. The phrase can mean more than the sum of the constituent words.
8. Words are descriptors and stimulators of emotion (anger, love)
9. Words can create impressions (onomatopoeia, rhyme, rhythm, alliteration)
10. Words are agents of interrogation
11. Words are agents of $4^{th}$ dimension. Time past, present & future.
    (both communicating & processing)
12. Words are agents of instructions
13. Words are agents of neural programming
14. Words are a means of organising the processing power of the Brain
15. Words are a means of constructing neural hierarchies of ascending complexity.
16. Numbers are subsets of Word structures
    a. Numbers provide a language of measurement and computation (arithmetic)
    b. Numbers provide a language of describe, define and measure shapes & spaces (geometry).
    c. Numbers provide a language to describe, define and measure symbolic formulae (algebra)
    d. Numbers are agents of relationships and the representation of information in diagrammatic and graphical form.
    e. Numbers can be used to build up formulae that can be built up to create models of systems that can be used to forecast events, test theories and devise alternatives.
17. Notations are subsets of Words
    a. Crotchets, Quavers,

b. $H_2O$,

18. Words are the agents of thinking

19. x

Programming
is the design of abstract patterns – new algorithms. It is almost pure thinking

**Thinking** is the creation of new ideas, concepts, answers. New neural connections, networks and structures

Thinking is the software of the brain. Programming is the software of computers

It is interesting to note that programming computers is a similar process involving the construction of hierarchies of patterns within an overall structure designed to achieve specific objectives. Lower order patterns are repeated frequently in various different parts of the system – the computing world usually calls them 'subroutines'. Similarly programs sit conceptually on top of each other. At the bottom are the machine code instructions, which nowadays few programmers know much, if anything about – they have disappeared below the conscious horizon. Above this sits the operating systems like the various versions and successors of 'windows'. Above this sits various applications, constructed in a series of micro subroutines, or patterns known as a programming language. Each micro subroutine is indexed by a word or words that have carefully prescribed meanings. Often an application will have a higher order means of varying the application to tailor the general system to fit the detailed needs of the final user. Lower order programs are usually compiled, higher order programs are interpreted.

Systems analysis is about designing the overall framework and architecture of an application. Programming is about filling in the detailed instructions to execute that application and involves designing building and integrating a plethora of patterns into an elegantly constructed whole. It is a task whose complexity is on the extreme edge of human capability and requires a degree of accuracy that human beings have never needed to deploy at any time in history. A computer has no common sense or consciousness of what it is doing in the way that all humans do, so these instructions have be designed to respond to every conceivable eventuality and combination of events, with a precision never before even contemplated.

Systems design requires a very vivid imagination. Designers and programmers commit their plans to paper but no one ever sees a program working: only the results. Creating a program is entirely cerebral: it involves designing abstract patterns - and as such is pushing out the frontiers of human knowledge and, arguably, modifying the structure of human thought in the same way that the invention of writing which similarly required human beings to be far more precise in the way they described things to avoid ambiguity. Thus, like the invention of words, then writing and printing, computing is a key driving force in the continuing evolution of the brain.

This reference to computing is useful because, although some systems are now extremely complex and carry our very sophisticated tasks, like winning chess games, there is not the slightest hint that computers have even as much conscious awareness as an 'Aplysia' or sea snail. What is different? Brains are different in three ways. Brains grow their circuits, thus software and hardware are one. Brains have an emotional dimension, and so can generate different responses to identical situations. In line with all other living beings, brains can initiate activities. Computers are entirely rule based and totally constrained to the limitations of their hardware and software.



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