TITLE PAGE

BIOLOGY AND MECHANISMS RELATED TO THE DAWN OF LANGUAGE

Chapter for book: ***'Homo Symbolicus' and the dawn of language***

Author:
George F R Ellis,
Mathematics Department,
University of Cape Town,
Rondebosch 7701,
Cape Town, South Africa.

Email: george.ellis@uct.ac.za

ABSTRACT:

This paper explores the functional and structural context for the emergence of language. The purpose of it all is prediction and problem solving in the social and ecological context. Crucial features of language include its indexical nature, its modular hierarchical structure, and its embodiment of recursion. Its implementation is enabled by the combination of bottom-up and top-down causation in the brain, which affects the way language is produced, received, and learnt. Language arises through an evolutionary process of development of motivational modules (primary emotions) that then motivate language development and usage, plus intellectual development of symbolic capacities, constrained by essential semiotic constraints. Visual thinking develops basic abilities of pattern recognition and classification, but it is music that can more effectively develop the key feature of recursion. The motivational impulse for language use starts with mother-child nurturing but moves on to the joy of imaginative play, which develops theories of other minds and basic symbolic abilities; it also easily includes music and song. Key steps towards language could be changes in neural connectivity allowing recursion to emerge, in the context of developing technological needs. There are possible archaeological traces of the crucial element of recursive patterns and recursive symbolism, but they will be suggestive rather than decisive.

[Main text: 7,216 words. Bibliography. One table, four figures].

Editors:

Christopher Henshilwood Christopher.Henshilwood@wits.ac.za
Francesco d'Errico f.derrico@ipgq.u-bordeaux1.fr
Mary Ann Meyers mmeyers@templeton.org

BIOLOGY AND MECHANISMS RELATED TO THE DAWN OF LANGUAGE

George Ellis, University of Cape Town

1: THE FUNCTIONAL AND STRUCTURAL CONTEXT

The emergence of language is partly a socially and environmentally based phenomenon, but equally it has a biological base. As well as social and functional needs, evolutionary arguments should take this link to biology into account. In biological terms, structure enables function, and hence study of language evolution must consider the neurological structure of the brain in relation to how it functions. Of course the nature of language itself is also central to this analysis, so key questions are, What are the crucial features of language that enable its extraordinary representative and communicative abilities? And how are they realised in neurological terms?

Like all truly complex systems, language has both a modular hierarchical structure (Simon 2001, Booch 2007) and an evolutionary origin (Christiansen and Kirby 2005). It is clear that social development requires language: without communication society cannot exist. As social cooperation greatly increases survival prospects, evolutionary processes will favour capacities that lead to language development (Burling 2007: 91, 146). The purpose of it all is prediction and problem solving in the social and ecological context. The functional basis is the embodied brain and its biological context. Its mode is via the nature of semiotic representation. The key functional element in representing complex aspects of reality is a modular hierarchical structure, with a class structure involving inheritance and the capacity for recursion. It is realised through grammar that is usage-based and embodied (Bergen and Chang 2003, Feldman 2006), rather than being rule-based.

The crucial biological feature whose emergence enabled the flowering of human language, separating us from all other animal species, is still unclear. A key question here is, Was the advent of language essentially due to some change in brain structure, which then inevitably led to social changes? If so, what was that change? (Striedter 2005). Or was it rather basically due to ecological and social changes, which then led to changes in brain structure? If so, what were these key changes? This chapter first looks at foundational issues underlying the discussion, and then at some evolutionary issues and possible archaeological implications.

2: THE NATURE OF LANGUAGE: CRUCIAL FEATURES

Language has crucial features related both to its semiotic function and to its embodied nature.

2.1 An embodied symbolic system. Language is a symbolic system (Deacon 1998) with a semiotic function (Trask 2007): its purpose is to convey meaning, facts, and concepts in a social context through systematic use of symbols. It represents the world of objects, actions, and qualities, as well as relationships, ideas, and theories. This representational function involves naming, indexing, and use of metaphor (Trask 2007, Lakoff and Johnson1980). Facts represented are both contingent (historical, geographical, and other specific features of the world and of narratives) and generic (universal patterns characterising the way it all works in general). The relation between these two features (concrete/specific and abstract/generic) is a key aspect of thought and of language, involving development of classes of entities and classification of specific instances.

While language has an abstract character, it is embodied via an equivalence class of physical representations; in particular it has spoken and written forms. Its existence enables the cumulative building up of understandings and ideas in individuals and in society, and (through technological means) their long-distance sharing in geographic terms as well as their storage and preservation in various media, enabling their propagation over long times. This storage of ideas in external media (ranging from diaries and memos to encyclopaedias and *wikipedia*) greatly facilitates our mental powers and underlies an exponential growth of knowledge (Clark 2008). Language attains its social power through enabling mediation of social interactions on a small scale, and through enabling the utility of mass media and communication systems on a large scale. These enable widespread dissemination of facts, ideas, and meanings, extending the cognitive web from local communication to a global system. Minds therefore cannot be understood on their own (Donald 2001): they are part of a society that is in turn part of a global intercommunication network.

2.2 Equivalence class of representations and embodiment. Physical realisation of language can be neural (in an individual's brain), spoken (sound), written (visual), electronic (digital), or in visually transmitted sign patterns (sign languages). The same structural patterns are embodied in these different representations. They are all enabled by the physical structure of the brain, which is hierarchically structured so as to enable an interplay of sensory interpretation and prediction, based on pattern recognition, classification, memory, and extrapolation (Hawkins and Blakeslee 2004). Meaning is embodied in an equivalence class of such surface representations: it is independent of whether language is spoken, written or signed, and of language family, dialect/pronunciation, and font. A profound ability of the mind, underlying the flexibility of language usage, is to recognize them all as functionally equivalent. The concepts represented are recognized as entities that exist in their own right, which can be labeled and represented in many different ways.

2.3 Key features of language. The major function of language is its labelling of specific and generic objects and instances, as well as abstract entities, through use of indices and symbols. Via recursion (Deacon 2003, Trask 2007: 244), this referential and representational nature can allow reference to itself, and hence disjunction from physical referents. Related key design features of language are (Trask 2007: 70):

- ***Arbitrariness***: the absence of any necessary connection between the form of a word and its meaning. This uncoupling of the signifier from the signified is crucial to representing objects symbolically (Striedter 2005: 337). It allows equivalence classes of representations to exist: the same meaning can be expressed in different symbolic forms and systems.
- ***Duality of patterning***: a type of structure, encoded in a grammar with a particular syntactical structure, in which a small number of meaningless units are combined to produce a large number of meaningful (semantic) units. This introduces the crucial feature of discreteness of structural units (the quantum principle), which can then be repeatedly combined as recognised and named higher level units, giving hierarchy and allowing arbitrary complexity of combinations to be built up through recursion. Its constituent structure is based on this principle (Trask 1999: 52-53).

- ***Stimulus-freedom***: our ability to say anything at all in any situation, so enabling discourse that is freed from the immediate situation and stimuli. This enables us to think off-line, i.e. without having to immediately act on what is thought about; hence it enables us to reflect on the past and plan for the future (Bickerton 2001). This facilitates the crucial feature of suppressing stimulus bound behaviours and replacing them with less determinate voluntary acts (Striedter 2005: 334, 344).
- ***Displacement***: the ability to speak about things other than here and now. This enables us to analyse theoretical situations and so indulge in imagination and abstract analysis based in past memories and future possibilities.
- ***Open-endedness***: the ability of language to say new things, virtually without limit. This is enables language to be a vehicle whereby creativity can emerge.
- ***Redundancy:*** the full message is entailed by part of the given text/message, hence one can determine the full message by partial information (if the context is known)**.** This enables effective communication: we can understand the message in the presence of distortion or noise.

A key feature of the way language functions is the use of ***metaphor***, which plays a major role in cognition and meaning-making (Lakoff and Johnson 1980, Sutter 2008). This is enabled by the features listed above, and takes place in the context of ***conceptual schemas*** and ***cultural frames*** (Feldman 2008: 135-148), which are the context of our understandings.

3: BOTTOM-UP AND TOP-DOWN CAUSATION

These features in turn are based in the functional structure of language, enabled by the physical structuring of the brain.

3.1 Functional structure. Language has a ***modular hierarchical structure*** (Booch 2007) that enables its completely flexible representational and social function. This structure is bound by strict semiotic requirements (Deacon 2003), leading to a necessary set of implicit rules, but with a great variety of possible realisations (different languages/dialects). Its hierarchical character is enabled by a class structure with inheritance, embodying the crucial feature of ***recursion*** (the occurrence in a sentence of a syntactic category containing within it a smaller version of the same category, based on chunking and labelling). "The recognition of a suitable set of syntactic categories allows us to analyse all the sentences of a language as being built up, by means of a fairly small set of rules allowing recursion, from just these few categories" (Trask 1999: 288). This is a very general way of handling complexity: recursion occurs whenever you break up a complex task into simpler tasks that are completed first (Hofstadter 1979: 127-131).

Reflecting and enabling the modular hierarchical structure of language, the brain also has a modular hierarchical structure (Beer 1981, Ch. 7; Hawkins 2004), in turn based in the hierarchical structure of its physical constituents (Scott 1995), as shown in Table 1. Major issues arise in the linkages between different scales in the brain - the relation of molecules to neuronal activity; of neuronal connectivity to brain function; of brain regions to cognitive function; of the brain as a whole to individual psychology; and of the individual to the social and ecological environment. A further major issue is how this physical hierarchical structure underlies and enables the hierarchical functional structure of language. This is of course part of the larger issue: how does brain structure underlie the complex functioning of the mind? (Koch 2004).

3.2 Bottom-up and top-down causation. Emergent behaviour is enabled by the combination of bottom-up and top-down causation in the hierarchy of complexity and causation (Ellis 2008) [Figure 1]. This feature occurs at all levels; in particular, in micro and macro aspects of the brain itself, in the relation of the brain to psychology, and in the relation of the individual to society It is enabled by the existence of equivalence classes of lower level states that correspond to single higher level states (Auletta et al 2008). The interaction between these two types of causation in the functioning of the human cortex is emphasized by Feldman (2006) and Hawkins and Blakeslee (2004), while the way it takes place as regards individuals in the context of society is nicely illustrated in Berger (1963), Berger and Luckmann (1967), and Donald (2001). Top-down causation has crucial effects both on causal relations, and on the way we understand them. It is also a key feature in both language production and understanding, where holding context in mind is crucial to understanding both speech and writing (Smith 1976); key processes in language production, reception, and learning are therefore top-down driven. Indeed the way meaning is embodied in the hierarchical structure of language is context-dependent all the way down: the individual units at each level (sentences, phrases, words, phonemes) only attain their meaning and function, and even pronunciation, in the larger context of the whole meaningful situation (Krashen and Terrell 1983, Goodman 2005).

The key element allowing new ideas and information to come into being is adaptive selection [Figure 2], which is a specific form of top-down causation guided by higher-level selection criteria (Ellis 2008) which enable multi-level selection to take place (Okasha 2006). The top-down nature of this causation is crucial to this process, enabling new kinds of entities to come into being. Indeed, David Sloan Wilson remarks (2009) that the transition from bottom-up to top-down dominated causation in the relation of mind to the society in which it is imbedded is a major evolutionary transition in the historical development of humanity, resulting in the emergence of the social order as a higher level entity in its own right, and a consequent change in the nature of the evolutionary processes at work. However, adaptive selection also occurs on functional and developmental timescales.

3.3 Production: Speaking and Writing. Speaking requires the physical ability to talk (vocal chords), and writing requires hands that can clasp and move delicately, plus a bipedal posture that allows them the needed freedom to operate. These are characteristically human features, although some animals do have some of these attributes (Striedter 2005). But one also needs the ability to form thoughts in the context of the current situation; this is where top-down causation occurs from that overall context to detailed thought processes. One then requires the ability to turn developing thoughts into a meaningful grammatical form, on basis of past patterns experienced and usage-based language skills. This involves top-down causation from past experiences of linguistic patterns, as discussed below.

3.4 Reception: Listening and Reading. Listening and reading are based on seeing and hearing, which are very ancient attributes in the animal kingdom, exquisitely developed in many higher animals as well as humans. Decoding syntax and grammar involves top-down causation from past experiences of linguistic patterns, similar to the processes involved in speech production. However listening and reading are essentially based in processes of understanding, involving expectation and prediction in the face of partial information and noise (Smith 1976). These expectations are based on current context and memory, so this is also a form of top-down causation from those higher level concepts, based on similar processes to those occurring in general cognition (Hawkins and Blakeslee 2004).

3.5 Learning. Language is learnt by experiential processes in a meaningful context (Smith 1976), supplemented by a combination of formal and informal instruction. This learning is an individual process of experimental development: hypothesis formation, trial and error, and imitation takes place in a social context of observation and experience. Like all human capacities, it is then embodied in a set of hierarchically structured automatized skills that are constructed in and constantly revised by consciousness (Donald 2001: 57). This process is driven by the need to understand and predict (an example of top-down causation), in the overall context of the search for understanding and for meaning (Hawkins and Blakeslee 2004). Thus it is based – through experience and usage -firstly on intention-reading and cultural learning; secondly on schematization and analogy; thirdly on entrenchment and competition; and fourthly on functionally based distribution analysis (Tomasello 2003: 295-307). This learning is enabled by *Latent Semantic Analysis* (Landauer et al 1998), resulting in an *Embodied Construction Grammar* (Bergen and Chang 2003, Feldmann 2006). Spoken and written language abilities are developed by variants of the same experiential process: meaningful experiences drive the process in a top-down way (Smith 1976). Bottom-up processes (formal teaching) are needed to supplement and systematise this learning process, but cannot replace it.

4: LANGUAGE MODULES AND THE DEVELOPMENT OF LANGUAGE

The brain has developed through evolutionary processes that have led to the development of the conscious mind and language.

4.1 Evolutionary development. Evolutionary processes apply both to living beings, and to culture (Richerson and Boyd 2005; Mesoudi et al 2006**)**. Language develops over time through adaptation in a social context, occurring via variation and then selection of language features according to communication utility (Burling 2007). The key point here is that according to standard genetic theory, nothing you understand or think influences the genes you pass on to your progeny, for they are fixed the day you are born. Hence any intellectual understandings you may develop cannot be directly selected for in biological terms, as they do not influence your genetic inheritance (although they do influence the likelihood of your passing on that unchanged genetic inheritance).

Rather, genetically based development results in general purpose intelligence (pattern recognition, classification, prediction) linked to memory (Hawkins and Blakeslee 2004), together with basic emotional modules (Panksepp1998) that are effective in guiding the development of analytic ability in general, and language ability in particular, in the individual (Greenspan and Shanker 2004). This takes place in his/her emotional context (Damasio 2000), with the social context crucially shaping individual minds in terms of understanding and language (Berger and Luckmann 1967, Donald 2001). That social context then reciprocally shapes the development of language itself: a culturally based evolutionary process (Richerson and Boyd 2005). This whole process favours genetic developments that lead to the propensity to develop language, but cannot lead to specific genetically determined language modules, for a variety of reasons I now briefly discuss.

4.2 Language modules. A large literature, largely based in linguistic analysis (for example, Pinker 1994), suggests that language processing is based in genetically determined language modules in the brain. Four problems make this extremely unlikely. First, it is developmentally unlikely that detailed connections in the cortex can be genetically determined, even though this does occur in other parts of the nervous system. Second, even if this was possible, there is not enough genetic information available to carry out this task; essentially, this is a key finding of the human genome project. Thirdly, as just mentioned, one can't directly select DNA to promote such connections because of the central dogma of molecular biology: the DNA one passes on to ones progeny is not affected by any of one's intellectual activities. And fourthly, the kinds of specific issues involved in detailed language processing would have to compete with hundreds of other factors affecting survival, and it is highly unlikely these specific items would dominate over all the rest and so result in genetic processes determining specific language modules, as originally envisaged by Chomsky.

An alternative view suggests language ability develops by conversion of genetically shaped general-purpose brain domains and capacities to language use. The way language is developed then is through the process of usage-based language acquisition, as explained by Tomasello (2003) and Feldman (2006). As explained by these authors, these processes have sufficient depth to undermine the Poverty of Stimulus argument: sufficient depth of experience to carry out this process is provided by everyday life (Tomasello 2003). The universal underlying features of all languages (sometimes interpreted as resulting from the deep structure of a generic Universal Grammar) are then understood as resulting from universal semiotic constrains intrinsic to their function (Deacon 2003).

Thus it is highly plausible that functional modular structures of language do not arise genetically, but rather have the restricted forms they do because of semiotic constraints. Then what is genetically determined in each individual is not specific language modules, but rather the capacity to develop language obeying these constraints. Hence in searching for the dawn of language, we do not have to explain genetically determined modules, but rather evolution of capacities that lead to the development of language. This has two aspects: the requisite intellectual capacities, and the needed emotional drivers; we discuss each below.

5: PATTERNS AND SYMBOLS: VISION AND MUSIC

What intellectual capacities and problem solving abilities underlie the development of language, and what hints of their presence could we hope to find in the archaeological record? Can we identify the intellectual capacities, and then propose other ways they may display their presence?

5.1 Pattern Recognition and classification. A first such key feature is the recognition of spatial and temporal patterns (Burling 2007: 82-84), and then categorisation: classifying and naming them, as discussed by Tomasello (2003), in the context of memory of past events and prediction of future happenings (Hawkins and Blakeslee 2004). Developing some form of conceptual structure is natural in higher animals (Burling 2007:69-72), indeed it is necessary for their functioning and survival, so they form proto-propositions (Hurford 2007). Categorization skills allow organisms to categorize different aspects of their world into a manageable number of kinds of things and events (Tomasello 2003: 4). Humans are able to go on to naming objects and events (labelling them symbolically), which develops naturally out of this: the essence of language is its symbolic dimension, with grammar being derivative (Tomasello 2003: 5, 13).

It is suggested by Hawkins and Blakeslee (2004) that the basic purpose of intelligence is memory-based prediction: "the brain is not a computer, but a memory based system that stores experiences in a way that reflects the true structure of the world, remembering sequences of events and their nested relationships and making predictions based on those memories. It is this memory-prediction system that forms the basis of intelligence, perception, creativity, and even consciousness". The use of symbolism and language crucially helps these purposes, their utility being based in the core features of language discussed above (Section 2). These abilities are based in the nature of local brain connections adapted to prediction and problem solving. How the core process of naming is implemented via neural connections is discussed by Hawkins and Blakeslee (2004: 147-153); this is the basis of symbolic systems. A key question is why these kinds of inter-level connections came into being in the cortex. Understanding experiences as mediated by the various senses must have been the core driver, and in particular, interpreting visual images in conjunction with sounds may have been crucial in leading to their development.

5.2 Visual thinking. Vision is one of the first detailed sensory capacities to have been developed, and is so effective and important that there have been various independent origins of eyes (Conway Morris 2003, Parker 2004). It has been suggested in a provocative analysis by Rudolf Arnheim (1969) that visual thinking is primary in the development of intelligence, with abstract thinking being secondary to it. The book description states, "He shows that even the fundamental processes of vision involve mechanisms typical of reasoning … our perceptual response to the world is the basic means by which we structure events, and from which we derive ideas and therefore language". This suggests the importance of the capacity to first represent relationships geometrically, identifying them as geometrical patterns, and then to express them abstractly, identifying them as abstract patterns. This is the start of symbolism, when one conjoins the ability to recognise both individual objects and classes of objects with the ability to associate some kind of symbol to each class of objects. This implies that the starting point for symbolic thinking is recognising patterns in space, hence the Blombos kind of pattern experiments are a starting point in such understanding. Additionally (Koch 2004), vision involves the same kind of "filling in" of information that is a characteristic feature of listening and reading, as emphasized above.

Hence vision strongly develops core pre-language abilities. However these are shared with all the higher animals: it is not clear that human visual understanding is greatly different from that of other animals. It is true that symbols are expressed in spatial or temporal relationships and patterns, and hence decoding them involves recognising such patterns; but it seems unlikely that such pattern recognition in humans is beyond that of many other higher animals, who through categorical perception can acquire a wide range of abstract concepts (Hauser et al, 2002: 1572, 1575). Furthermore, the progression from pictorial representation through icons to hierarchically structured recursive symbol systems (see Figure 3) is, in intellectual terms, a natural progression (Burling 2007: 78-82), but only if the key technology (some form of paper and pen or pencil, or its equivalent) is available: without them, even if the idea is there, actually implementing them in physical terms is too cumbersome to be practical. Indeed, a key point is that visual thinking only weakly, if at all, develops the key feature of recursion. While fractal patterns occur in nature and in some art, such as Escher's work, they are not a central feature of vision and visual understanding. Recursion is possible in sign language, but again is technically demanding and therefore not particularly natural and easy. Something else must be involved in addition to vision.

5.3 Grammatical forms and music. Music and language each have complex hierarchical structures with an associated syntax. Together they are universal in human societies, and are unique to our species (Levitin 2006). They can be claimed to have interesting similarities in terms of their `syntactic architecture' (Patel 2006: 267), and to share a number of basic processing mechanisms with an overlap in the neural areas and operations that provide the resources for syntactic integration (Patel 2006: 283). Singing and instrumental playing help refine motor skills needed for speech production and writing. Listening to music involves processes of expectation, prediction, and perceptual completion (Levitin 2006: 72, 101, 169-172), just as reading does (Section 3 above).

Thus music development would have encouraged the same intellectual abilities and motor skills as are needed for language, and may have played a more specific role in language development than vision. It would have had a deep effect on evolutionary psychological development because of the strong emotional power of music and dance, ensuring they played a major role in social bonding and cohesion, which thereby justifies its evolutionary importance. In particular, dance and music are associated with play, which is important for higher-level integrative processes (Levitin 2006: 262) and specifically in language development (see the following section). Most important of all, music commonly entails recursive structures (Patel 2006: 265), which are key in the structure of language, in both cases allowing its generative nature. The progression shown in Figure 3 is much more easily attained in vocal than written form, because hierarchy and recursion are naturally developed through music and song: there is no technical barrier to their implementation.

5.4 Development of Recursion A key feature in the development of language is the emergence of recursion in symbolic systems (Deacon 2003), enabling abstract thought patterns to emerge. "Recursion is pervasive in the grammars of the languages of the world, and its presence is the chief reason we are able to produce a limitless variety of sentences of unbounded length just by combining the same few building blocks" (Trask 1999: 244). Thus a crucial aspect of language is identifying as a single unit and naming compound experiences or concepts, thus allowing hierarchical structuring and recursion (building up patterns of patterns). This key ability for language (Hauser et al 2002, Fitch et al 2005, Burling, 2007: 35, 172) and computer languages (Roberts 2008: 546-558) must be based in specific aspects of local neural connections, involving specific kinds of connections enabling naming procedures to be applied to names themselves. This type of neural connectivity, presumably involving links from higher levels of structure to lower levels, should be characterisable in the same kind of way that Hawkins and Blakeslee (2004) identify the neural bases of naming.

Consequently, one might envisage the key step in language development as being the development of neural connections allowing recursion, either directly as the result of some advantageous genetic mutation, or as a by-product of some other-directed advantageous mutation (Hauser et al 2002, Fitch et al 2005). The former seems far more probable: it is difficult to envisage what advantageous mutation could have led to this result as a by-product. In any event, as soon as the utility of this new ability was realised in developmental terms, perhaps first in relation specifically to music and singing (associated with vocal cord development) and then (through them) in imaginative play as a general mental ability, it would have become so important in mental life as to have demanded massive new physical resources, thus requiring major expansion of the cortex. Thus on this view, that crucial physical development (Striedter 2005) is regarded as being a result of, rather than the cause of, increased processing needs. A modest selective advantage in terms of allowing more effective cooperation between individuals will allow language and grammar to evolve by a conventional Darwinian process (Dunbar 2005).

Overall, I suggest that generic sensory interpretation, and visual thinking in particular, provided the broad basis for development of the abilities needed for language development and usage, with social interactions and play naturally developing the basis of symbolic reference through pointing and embryonic words. The specific capacities needed for language utility were greatly enhanced by the development of musical activities, evolving into singing and dancing. This provided a considerable part of the basis for language because of a deep connection between musical and linguistic syntax in the brain (Patel 2008: 268), and in particular the use of recursion in musical syntax (Patel 2008: 265).

If this view is true, it should have several testable consequences:

- First, the initial variation leading to recursive type structures would have been random (as there is no way it could have been directed), but it would have had a genetic basis, as otherwise it would not have been a heritable quality; hence there should be some determinable genetic linkage to this property. Either an identifiable set of genes, or some identifiable epi-genetic processes, should be the key to making it possible.
- Second, it should result in some specific type of neural connectivity whereby recursive naming takes place, of the generic nature identified by Hawkins and Blakeslee (2004). This type of structure should eventually be identifiable.
- Thirdly, the resulting ability for recursive thought should then be manifested more or less simultaneously in various intellectual domains, particularly in language and music, but also in others such as patterns of play and art, and in technology.

6: THE IMPORTANCE OF EMOTIONS IN THIS DEVELOPMENT

A key issue is what motivational structure drove these developments. Intelligent life is not a purely rational affair, as some analyses suggest (e.g. Gintis 2007). Rather emotional drivers largely determine to what use intellect is put (Damasio 1995).

6.1 The motivational impulse for language use. The motivation for language use is based in the functional importance of emotions at the psychological level, associated at the neuronal level with non-local neuronal connections such as the monoamine systems (Kingsley 2000, pp.131-134). Particularly important here are the mother-child emotional connection, the key to early language development (Shore 1995, Greenspan and Shanker 2004), and the developmental significance of play in learning (Vygotsky 1978: 92-104) and specifically in language (Paley 2004), a key to later language development. These features occur in the ambient social and ecological environment, where top-down action from the social level to individuals provides the integrated context for emergence of language, and plays a significant role in determining the outcome. The development of language is crucially dependent on the emotional drivers that power the desire to communicate with others and assure the individual of their place in society. This leads to a key feature in language acquisition, namely *intention reading* (Tomasello 2003).

These drivers are based in the genetically determined primary emotional systems that are our evolutionary heritage from our distant ancestors (Panksepp 1998, 2008). According to Stevens and Price (2000), two key such systems are the Affiliation/Belonging system, and the Rank/Status system. These systems must therefore be important in communication, symbolism, and language development. This is confirmed by much evidence, the importance of the affiliation/belonging system in language development of children being emphasized by Greenspan and Shanker (2004), while that of the Rank/Status is emphasized by d'Errico (2009). Initial language development is based on the primary emotional bond of an infant with its mother/primary carer (Greenspan and Shanker 2004, Schore 1994) but then is developed through social interaction, particularly within the family context and peer group situations. These both underlie the development of joint attention and imitation, which are key features of human language development (Burling 2007: 72-78).

A further key emotional system associated with language development is the Play system, discussed by Jaak Panksepp (1998, 2008). This system, with its associated feelings of joy and fun and behavioural patterns of laughter, is a key foundation for learning and the development of imagination, which is why we share it with all our mammalian relatives, in particular the primates (Pellegrini and Smith 2005). However a probable major feature here was the change from rough and tumble play to imaginative play (Paley 2004, Smith 2005, Toronchuk and Ellis 2005), which probably played a significant role in developing theories of other minds. Evidence for this is the fact that weak functional and pretend play is a contributor to autism (Charman 2003).

6.2 The basis in developmental biology and evolution. By what kind of mechanism can brain plasticity lead to the formation of these effective modules in this adapted way? This has to be an adaptive process, of the kind labelled `Neural Darwinism' by Gerald Edelman (1989), implemented by neuromodulators such as dopamine broadcast to the neocortex from the limbic system (thereby forming Edelman's "value system" that guides the direction of plasticity). But the limbic system is the seat of emotional processes, so the fitness function guiding these adaptive processes is provided by the genetically determined primary emotional systems of the kind examined in detail by Panksepp (1998). Hence, evolutionary pressures in the ancestral environment developed various psychological traits that are experienced by us as emotions and feelings, which result in behaviour enhancing our evolutionary adaptation to the ancestral environment. Thus evolutionary processes enable brain development through genetically determined primary emotional modules (Panksepp 1998) that guide cortical development via a process of Neural Darwinism responding to daily experiences and events (Edelman 1989), with a crucial affective nature (Ellis and Toronchuk 1995).

What is inherited, then, are basic cognitive abilities rather than specific cognitive modules, plus the basic sensory and emotional systems that guide the use of cognition. Any effective cognitive modules that result develop from interactions of these systems with the social and physical environment, with the salience of reactions guided by the inherited emotional systems (Ellis 2008a) [Figure 3]. Overall this process is of Darwinian rather than Lamarckian nature, because it does not propose genetically determined modules with specific cognitive content, but rather genetically determined emotional systems that guide cognitive development.

7: KEY STEPS TOWARDS LANGUAGE

Many of the basic cognitive capacities that allow language development (Tomasello 2003: 4) are shared between us and other higher mammals. The dramatic increase of brain size in relation to body weight (which may have been either the cause or the result of other changes) enables greatly increased memory and processing capacity. Together with physiological improvements in terms of speech production, these make speech physiologically possible. However this is not sufficient: intellectual development is crucial also. I suggest on the basis of the above discussion that two crucial emergent features distinguishing human beings from other animals in both developmental and evolutionary terms are changes in the emotional system underlying language use, and changes in neural functional capacity so as to allow recursive thought.

7.1 Changes in Physiology. The physiological changes mentioned above are crucial for language development, in particular, improved physical ability to form sounds and a greatly enlarged brain and associated greater memory capacity are certainly needed. But it is not clear if these are cause or effect. What caused them to happen? Brain size is crucial in terms of increasing both total computing power and memory capacity, and also because it necessarily promotes modularity (Striedter 2005:339-340), but this is not enough by itself (for there are other animals with larger brains!). We need something more than just brain size to make language fly.

7.2 Changes in the Social and Ecological context. Language development takes place in a social context where symbols are used for communication of social and environmental understandings so as to form a distributed cognitive network (Donald 2001). Thus its development needs the right social context of a society with common needs and purposes. As emphasized by David Sloan Wilson (2009), there will be particular environmental situations where these will be stronger drivers for language development than others. Crucial drivers were the need for social communication to underlie coping and cooperation, enabled by development of a theory of mind and intention reading (Tomasello 2003: 3, 31), together with the child-caring and raring needs due to the long period between birth and adulthood. But no obvious change has been identified causing much greater need in these regards than in primates: there seems a continuity with them rather than discontinuity, except perhaps in regard to development and use of technology.

It is certainly a possibility that development of technology was a major driver of the need for the kind of better communication afforded by language. According to Jacob Bronowski, "The largest single step in the ascent of man is the change from nomad to village agriculture … settled agriculture creates a technology from which all physics, all science takes off"" (Bronowski 1976: 64, 74). But again it is not clear if that is the driver or the result of language change. The features of language listed in section 2.3 above would have been very helpful in developing technology; perhaps one can make the case that language and technology co-evolved as equal partners, the rapid development at later times simply being the result of the essential nature of exponential growth. The idea that development of technology was the key contextual partner in language development seems a very viable proposal (see the articles in d'Errico and Backwell 2005, particularly those by Tobias and by Parkington et al). But what was the crucial threshold leading to the take-off of the language-technology partnership? It is argued above that this would have been when this co-evolution led to the discovery of the principle of recursion in symbolism.

Perhaps times of change associated with new environments are particular stressors demanding more effective communication, and so driving communication and language development. Could the move out of Africa, between 50,000 and 100,000 years ago, perhaps have been one such stressor? The need to communicate is much greater in a strange environment than in a known environment, so this move may have been the kind of change that strongly encouraged development of better communication abilities. This would have been greatly assisted by the associated freeing-up from debilitating diseases that resulted from the move out of Africa (Reader 1998: 234), allowing the mind to flourish in an unprecedented way. This was of course recent in evolutionary terms, but perhaps gene-culture co-evolution (Richerson and Boyd 2005) could have occurred and allowed this event to become of evolutionary significance for the present day. Again this would have been related to development of technology, related both to travel and to adapting agriculture to new contexts. This might seem a promising context for a leap forward in language.

7.3 Emotional development: The nature of play, other minds. It has been emphasized above that mother/child bonding is key ingredient in language development, but this is essentially the same as in other higher animals – apart from the use of language, which is what we are trying to explain! There is no obvious discontinuity here between pre-humans and humans. But the transition from rough-and-tumble play to imaginative play, based in the effects of non-local neural connections and resulting in displaced symbolic activity, could be a key development in terms of freeing up creativity and encouraging development of a theory of mind, as well as basic communication skills. This is a promising avenue for promoting language abilities, particularly because music and song are natural aspects of play. This kind of powerful joyful activity develops pre-language abilities in terms of listening, production of sounds, and theory of mind, as well as developing basic grammatical skills.

7.4 Intellectual development: Music as a precursor to grammar. It has been argued above that music and song develops skills of production and grammatical patterning on the one side, and the vocal tract on the other. It uses the same processes as reading: expectation, prediction, and perceptual completion (Levitin 2007). And it develops basic principles of syntactic organisation employed by the human mind (Patel 2008: 267), including recursive structures. The latter feature may be a crucial role played by music and singing in providing a stepping stones on the way to language (Burling 2007: 124-128).

7.5 Intellectual development: Emergence of Recursion. It has been argued above (in agreement with Hauser et al 2002, Fitch et al 2005) that the single most important key feature in the emergence of language is the development of recursion in symbolic systems, enabling abstract thought patterns to emerge. I suggested this is enabled by specific classes of neural of connections, initially emerging through genetic chance but then rapidly spreading because they provide a key aspect of the development of higher level thought and language.

But then what was the initial driver for recursion to develop from some chance genetic event? Maybe that was its occurrence in music (Patel 2008: 243, 265) and singing, providing the emotional context in which it would flourish until its intellectual powers became evident. It was engaged in initially because of its emotional charge, but then resulted in development of intellectual capacities that flourished in their own right and laid the proper ground for language development. The proposal is that this then greatly enhanced the need for neurological resources, leading to the famous expansion of cranial capacity (Striedter 2005).

7.6 Overall proposal. Overall the proposal is that vision lead to the development of the general purpose abilities and understanding that underlie intelligence and language, but did not lead to language-specific features. The key element was the development of recursive thought, presumably an ability that initially occurred through some genetic mutation that led to a generic type of wiring involving top-down connections in the cortex enabling chunking and labelling. The emotional driver for the needed intellectual development could have been the transition from rough and tumble play to imaginative play, which would have naturally also been expressed in music and then in song, which are natural emotional drivers. Indeed recursion may have come about to some degree through musical development, which naturally contains such features, and would also have helped develop the musculature needed for speech. Whether enabled by music or not, recursion then enabled such an explosion of cognitive power that a major expansion of the cortex was required to take advantage of its possibilities. The contextual situation that may have helped drive this all could have been firstly the development of new technologies requiring analytical abilities and social communication, and secondly the move out of Africa into new environments. But then again, maybe that move was inspired by the new intellectual abilities that developed through recursive thought.

Indeed one should recognise the multimodal nature of meaning-making and cognition: each of the modes of sending and communicating has a semiotic nature and they support each other (Kress 2000, Sutter 1980). However it has been suggested above that technology, music, and recursion may have been the key links through to developing language capacity.

7.7 Archaeological traces. Might any of the features discussed here might leave some traces in the archaeological record? There are many such links to the above narrative, most already being explored; the point here is that this search can be related to aspects of how the brain underlies language, as outlined above, which might possibly help focus the search.

There are of course records of group membership, related to belonging/ cohesion, and symbols of social status, related to rank/power; these are a small step along the symbolic route. One might search further for records of music and dancing, argued above to be key players in the development of language, seeing if any traces of recursive patterning occur in these records. One can search for symbols and artefacts in the archaeological record associated with play: toys as symbols used in imaginative play, playing boards, scoreboards, and so on. Could any of the Blombos patterned artefacts be of this nature? And in particular do any show signs of recursive features, such as fractal-like patterning? One might ask if there is any way of identifying traces recursive thought in any other artefacts, for example those that are purely decorative. And finally the link to technology is crucially important, as evidenced in other articles in this book. Perhaps recursive patterning can be found in tool design, implying it is embodied in manufacturing techniques. If so, that would be a significant discovery as regards thought patterns essential to language. However it has to be admitted they will individually be suggestive rather than decisive. A powerful case will only be made by a collection of evidence of all kinds, of such a nature as to provide a cumulative case.

REFERENCES:

Arnheim, R (1969): *Visual Thinking* (Berkeley: University of California Press).

Auletta, G, Ellis, G F R, and Jaeger, L (2008): "Top-Down Causation: From a Philosophical Problem to a Scientific Research Program". *J R Soc Interface* **5:** 1159-1172.

Beer, S (1981): *Brain of the Firm* (Chichester: John Wiley).

Bergen, B K and Chang, N (2003): "Embodied Construction Grammar in Simulation Based Language Understanding". In *Construction Grammars(s): Cognitive and Cross-Language Dimensions*, Ed, J-O. Östman and M. Fried (John Benjamins).

Berger, P (1963): *Invitation to Sociology: A Humanistic Perspective.* (Doubleday, New York).

Berger, P and Luckmann, T (1967): *The Social Construction of Reality: A Treatise in the Sociology of Knowledge* (New York: Anchor).

Bickerton, D (2001): *Language and Human Behaviour* (Seattle: University of Washington Press).

Booch, G (2007): *Object-Oriented Analysis and Design with Applications* (Addison-Wesley).

Bronowski, J (1976): *The Ascent of Man* (London: The BBC).

Burling, R (2007): *The Talking Ape: How Language Evolved* ((Oxford: Oxford University Press).

Charman, T (2003): "Theory of mind and the early diagnosis of autism". In *Understanding other minds: Perspectives from developmental cognitive neuroscience*, Ed. S Baron Cohen, H Tager-Flusberg, and D J Cohen (Oxford: Oxford University Press).

Christiansen, M and Kirby, S (Eds.) (2005), *Language Evolution* (Oxford: Oxford University Press).

Clark, A (2008): *Supersizing the Mind: Embodiment, Action, and Cognitive Extension* (Oxford: Oxford University Press).

Conway Morris, S (2003): Life's Solution: Inevitable Human Beings in a Lonely Universe (Cambridge: Cambridge University Press).

Damasio, A (1995): *Descartes' error: Emotion, reason, and the human brain* (New York: Avon).

Damasio, A (2000): *The feeling of what happens: Body, emotion and the making of consciousness* (London: Vintage).

Deacon, T (1998): *The symbolic species: The co-evolution of language and the brain* (W. W. Norton & Company).

Deacon, T (2003): "Universal Grammar and Semiotic Constraints" In *Language Evolution*, Ed. M Christiansen and S Kirby (Oxford: Oxford University Press), 111-139.

d'Errico, F. (2009): This volume.

Donald, M (2001): *A mind so rare.* New York: Norton.

Dunbar, R I M (2005): "The origin and subsequent evolution of language". In *Language Evolution*, M Christiansen and S Kirby, Eds. (Oxford: Oxford University Press), 219-234.

Edelman, G (1989): *Neural Darwinism: The theory of group neuronal selection*. Oxford: Oxford University Press.

Ellis, G. F. R. (2008): On the nature of causation in complex systems. *Transactions of the Royal Society of South Africa, **63***: 69-84.

Ellis, G F R (2008a): "Commentary on `An Evolutionarily Informed Education Science' by David C Geary". *Educational Psychologist* **43** (4), 1-8.

Ellis, G F R & Toronchuk, J (2005): Neural development: Affective and immune system influences. In R. D. Ellis & N. Newton (Eds.), *Consciousness and emotion*: *Agency, conscious choice, and selective perception*, 81-119. Amsterdam: John Benjamins.

Feldmann, J (2006): *From Molecule to Metaphor: A Neural Theory of Language*, (Cambridge, Mass: MIT Press).

Fitch, W T, Hauser, M D, and Chomsky, N (2005): "The evolution of the language faculty: clarifications and implications". *Cognition* **97**: 179-210.

Gintis, H (2007), "A framework for the unification of the behavioral sciences". *Behavioral and brain sciences* **30**, 1–61.

Goodman, K (2005): *What's Whole in Whole Language: 20th Anniversary Edition.* Muskegon, MI: RDR Books

Greenspan, S and Shanker, S (2004): *The first idea: How symbols, language, and intelligence evolved from our primate ancestors to modern humans* (Cambridge, Mass: Da Capo Press).

Hauser, M D, Chomsky, N, and Fitch, W T (2002): "The faculty of language: What is it, Who has it, and How did it evolve?" *Science* **298**, 1569-1579.

Hawkins, J and Blakeslee (2004): *On Intelligence* (New York: H Holt & Co).

Hofstadter, D R (1980): *Gödel, Escher, Bach: An Eternal Golden Brain* (Harmandsworth: Penguin books).

Hurford, J R (2007): *The Origins of Meaning. Language in the Light of Evolution* (Oxford: Oxford University Press)

Kingsley, R (2000): *Concise text of neuroscience* (Philadelphia: Lippinscott, Williams and Wilkins).

Koch, C (2004): *The quest for consciousness: A Neurobiological approach* (Englewood, Co: Roberts and Company).

Krashen, S. D., & Terrell, T. D. (1983): *The natural approach: Language acquisition in the classroom* (San Francisco: Alemany Press).

Kress, G (2000): "Multimodality". In *Multiliteracies: Literacy and design of social futures*, Ed. B Cope and M Kalantzis (London: Routledge), 182-202.

Lakoff, G and Johnson, M (1980): *Metaphors we live by* (Chicago: University of Chicago Perss).

Landauer, T K, Foltz, P W, and Laham, D (1998): "An Introduction to Latent Semantic Analysis". *Discourse Processes* **25**, 259-284.

Levitin, D J (2007): *This is your brain on music: the science of a human obsession* (London: Plume).

Mesoudi, A, Whiten, A, and Laland , K N (2006): "Towards a unified science of cultural Evolution." *Behavioral and brain sciences* **29**, 329–383

Okasha S (2006): *Evolution and the levels of selection* (Oxford: Oxford uNiversity Press).

Paley, V G (2004): *A Child's Work: the Importance of Fantasy Play* (Chicago: University of Chicago Press).

Panksepp, J (1998): *Affective neuroscience: The foundations of human and animal emotions* (Oxford: Oxford University Press).

Panksepp, J (2008): "The Power of the Word May Reside in the Power of Affect". *Integr Psych Behav* **42**: 47-55.

Parker, A (2004): *in the blink of an eye: how vision kick-started the big bang of evolution* (London: Free Press).

Patel, A D (2007): *Music, Language, and the Brain* (Oxford: Oxford University Press).

Pellegrini, A D, and Smith, P K (2005): *The Nature of Play: Great Apes and Humans* (New York: The Guilford Press).

Pinker, S (1994): *The Language Instinct* (London: Penguin Books)

Pinker, S and Jackendoff, R (2005): "The faculty of Language: What's special about it?". *Cognition* **95**: 201-236.

Reader, J (1998): *Africa: A Biography of the Continent* (London: Penguin Books).

Richerson, P J and Boyd, R (2005): *Not by Genes Alone: how culture transformed human evolution* (Chicago: University of Chicago Press).

Roberts, E S (2009): *Java: An introduction to computer science* (Boston: Addison Wesley).

Schore, A N (1994): *Affect regulation and the origin of the self: The neurobiology of emotional development* (Hillsdale, NJ: Erlbaum).

Schreuder, M (2006): "Recursion in phonology". Chapter 4 in *Prosodic Processes in Language and Music,* PhD Dissertation, Rijksuniversiteit Groningen, The Netherlands. ISBN 90-367-2637-9.

Scott, A (1995): *Stairway to the mind* (New York: Springer Verlag).

Simon, H A (2001): *The sciences of the artificial* (Cambridge, Mass: MIT Press).

Smith, F (1976): *Reading* (Cambridge: Cambridge University Press).

Smith, P K (2005): "Social and pretend play in children". In *The Nature of Play: Great Apes and Humans*, Ed, A D Pellegrini and P K Smith (New York: The Guilford Press), 173-209.

Sutter, J (2008): "Multimodality: Moving beyond `language'/rethinking 'meaning'". *Language Issues* **20**: 53-60.

Stevens, A, and Price, J (2000): *Evolutionary psychiatry: A New beginning*. (New York: Taylor and Francis).

Striedter, G F (2005): *Principles of Brain Evolution* (Sunderland, Mass: Sinauer Associates)

Tomasello, M (2003): *Constructing a language: A usage-based theory of language acquisition* (Cambridge, Mass.: Harvard University Press).

Toronchuk, J. A & Ellis, G. F. R. (2005). *Affective neuronal group selection: The nature of the primary emotional systems*. Unpublished manuscript, University of Capetown. Available at http://www.mth.uct.ac.za/~ellis/AND%20II.doc.

Trask, R L (2007): *Language and Linguistics: The Key Concepts* (Abingdon: Routledge).

Vygotsky, L S (1978): *Mind in Society: The development of higher psychological processes* (Cambridge, Mass: Harvard University Press).

Wilson, D S (2009): "The human major transition in relation to symbolic behaviour, including language, imagination, and spirituality". This volume.

Level 8	***Sociology/Economics/Politics***
Level 7	***Psychology***
Level 6	***Physiology***
Level 5	***Cell biology***
Level 4	***Biochemistry***
Level 3	***Chemistry***
Level 2	***Atomic Physics***
Level 1	***Particle physics***

Table 1*: The hierarchy of structure and causation.* *This figure gives a simplified representation of this hierarchy of levels of reality (as characterised by corresponding academic subjects) in living beings .Each lower level underlies what happens at each higher level, in terms of causation. For a more detailed description of this hierarchical structure, see http://www.mth.uct.ac.za/~ellis/cos0.html.*

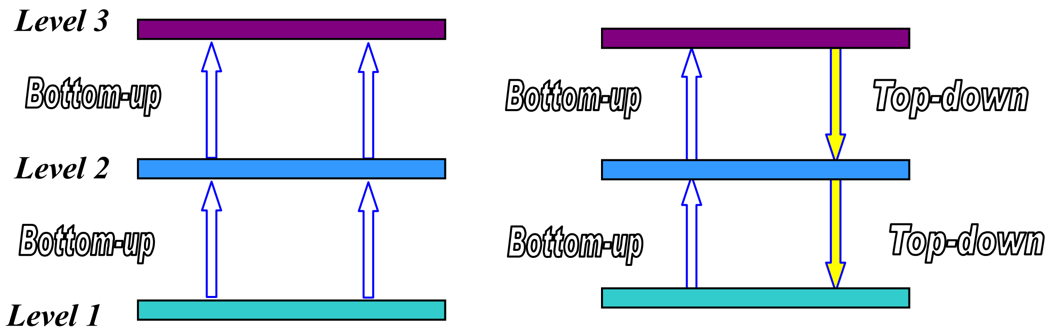

Figure 1a: Bottom-up causation only.

Figure 1b: Bottom-up and Top-down causation

Figure 1: ***Bottom-up and Top-down causation.*** *The fundamental importance of top-down causation is that it changes the causal relation between upper and lower levels in the hierarchy of structure and organisation, cf. the difference between Fig 2a and Fig 2b.*

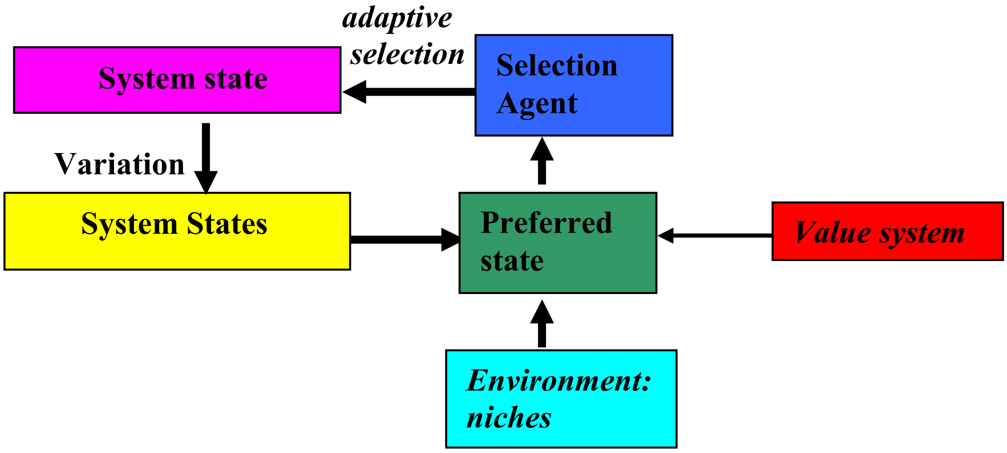

Figure 2: ***Adaptive selection***. *The meta-goals embodied in the value system do not lead to a specific final state: rather they lead to any one of a class of states that tends to promote the meta-goals. Thus the final state is not uniquely determined by the meta-goals; random variation influences the outcome by leading to a suite of states from which an adaptive selection is made in the context of both the value system and the environment.*

Pictorial representations ➔ Icons ➔ Indices and Symbols

➔ hierarchically structured symbolic systems

➔ hierarchically structured recursive symbolic systems.

Figure 3: ***Evolution of key characteristics of language.*** *A natural progression occurs in visual symbolic systems (Burling2007) , but only if the key technology (some form of paper and writing instrument) is available.*

Evolution ➔ genetically determined emotional systems;

Emotional systems + experience ➔ effective folk psychology behaviour

Effective folk psychology behaviour ➔ learning effects.

Figure 4: ***Evolution and effective psychological modules.*** *The way emotion underlies the existence of effective psychological modules. The behavior that gets inbuilt in effective folk modules will be suitably tuned ab initio to the culture in which the individual lives, because they are created through interaction with that culture. This experiential shaping of these systems to fit the local environment is an aspect of the crucial feature of brain plasticity (Donald, 2001).*
