Affective Neuronal Group Selection II: The Nature of the Primary Emotional Systems

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Abstract: *Higher brain functions are sculpted on the basis of the "hard-wired" primary emotions through the process of Affective Neural Darwinism. Here we make a tentative new proposal as to the nature of the primary emotions, based mainly on a combination of the work of Jaak Panksepp on affective neuroscience, the work of Stevens and Price on evolutionary psychiatry, and data on animal behaviour and neurology. In particular we suggest that in addition to the systems identified by Panksepp, there is substantial evidence for a "hard-wired" Ranking affective system in humans and other mammals, as well as a Disgust system which originally functioned to protect against toxins.*

1: Introduction

In a previous paper (Ellis & Toronchuk 2004, hereafter referred to as AND), we pointed out how Edelman's Neural Darwinism (Edelman 1989, 1992; Edelman & Tononi 2001), dealing with how brain development and function can be well understood in terms of a process of natural selection applied to neural connections, is naturally complemented by Panksepp's formulation of Affective Neuroscience (Panksepp 1998, 2001), addressing how neurobiological systems mediate the basic emotions. We discussed how major features of the basic value system crucial to Edelmann's neural Darwinism can be elucidated by the affective neuroscience of Panksepp, and conversely how important aspects of the mechanism by which valenced affective feeling states provide fundamental values for the guidance of behavior can be explicated by linking basic emotions to neural Darwinism (hence "Affective Neural Darwinism" or "Affective Neuronal Group Selection").

In particular, we proposed that the secondary emotions and intellect are developed in each individual through the developmental influences of the primary emotional systems, these systems together with the immune and endocrine systems acting as the Value System envisaged by Edelman and Tononi. Thus the primary emotions provide the core nature of the value system guiding the refinement of synaptic connections as the individual interacts with his or her physical and social environment.

It follows that elucidation of the specific nature of these primary emotional systems is crucial to understanding the way the brain functions and structures itself. In this paper, we make a new proposal as to the nature of the primary emotional systems. This proposal is summarised in Table 1 of this paper (supplemented by Tables 2 and 3),

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presenting the evolutionary needs met, and in Table 4, showing the associated neuromodulators and neural pathways.

This extension of our previous paper relates the proposals of AND to issues in evolutionary history, and in particular begins to answer some of the questions posed there as regards the nature of the primary emotions. It brings into play as evidence not only data from animal behaviour but also the burgeoning field of evolutionary psychiatry pioneered by Price (1967), and summarized in Stevens and Price (2002; see also Price, Gardner & Erickson 2004; Gardner & Wilson 2004; McGuire & Troisi 1998; Gilbert 1989).

We refer to the neural pathways involved in these emotions as being "hard-wired" in the sense that although all synaptic connections result from the combined action of genetic, local environmental factors during embryonic development, and external environmental influences before and after birth, some pathways are more dependent on genetic mechanisms, laid down earlier in development, and less influenced by postnatal environment than are other pathways. These primary emotional pathways would be less plastic than those used in secondary emotions, cognition and skilled motor behaviours. Panksepp has stressed that the differences between primary or prototypical emotions and secondary emotions such as shame and guilt, include differences in sensory input, neurochemicals and location of neural pathways. Primary emotions are instantiated in more ancient medial and ventral brainstem pathways, richer in visceral innervation, and utilize a variety of visceral-neuropeptides (Panksepp 1998, 2003). Although primary emotions involve conscious components, we adopt the view of Berridge (2003a) that they also have unconscious core aspects which predate the evolution of consciousness.

We discuss below several additional criteria, based on evolutionary insights, which we propose for identification as a primary emotion. Basically they are that (a) the emotion has already been identified on the basis of psychological studies as an emotional system in humans or in animals [3], (b) has been associated with particular neural circuitry through imaging techniques, neural excitation, and/or lesion studies, (c) has been associated with a particular combination of neurotransmitters and/or neuromodulators, (d) there is a convincing case for the system in terms of evolutionary psychological needs solidly related to survival, and (e) is supported from animal behaviour studies and/or current psychiatric observations. Thus we require an account of why the primary emotion listed is effective in functional terms, indicating how it is capable of altering evolutionary survival rates, and how its anatomical and physiological distinctiveness is causally effective in the processes of Affective Neural Darwinism[4].

The proposal presented here is based on previous analyses of the nature of the primary emotional systems, together with insights coming from evolutionary psychiatry (reviewed in Stevens & Price 2002, hereafter referred to as EvPs). What is new here is, firstly, the specific *set of criteria* we propose for identification of primary

[3] And so satisfies the functional criteria laid out on p.48 of Panksepp (1998).

[4] One would like to identify all the associated neurotransmitters, neuromodulators and neuropeptides, however this is difficult because of the interactions between the various systems – so they are often activated in concert with each other – and because different receptor subtypes are often involved in different functions.

emotional systems, and secondly, the resulting *proposal for a complete set of primary emotions*, extending previous such proposals.

In a sense this list is implicit in the existing literature, however as far as we are aware it has not previously been made explicit. It takes into account previous proposals by Darwin (Darwin et al. 2002) and Ekman (1972), summarised in Griffiths (1997), and by Damasio (2000) and Berridge (2004), but is based primarily on the work of Panksepp (1998, 2001, 2004), because his is the most comprehensive study of the overall systems of emotions based on extensive neuroscience data (a review by Watt (1999) describes Panksepp's 1998 textbook as "the first attempt at a genuinely comprehensive coverage of the basic neural systems that generate emotionality in the mammalian brain ".).

Thus the present work is proposed as an extension of the work of Panksepp, in the light of evolutionary psychiatry and animal behaviour, and supplemented on the basis of work by other authors on the nature of emotional systems.

In considering whether the list proposed here is complete or not, we explore briefly whether there might be a further primary emotional system related to *feelings of right and wrong* (as far as we are aware this possibility has not been considered before, despite the well-known literature on the supposed evolutionary mechanisms for the evolution of altruism). We tentatively propose these feelings may be related to secondary rather than primary emotional systems. However we also point out the difference between these feelings and true normative systems that underlie ethical behaviour.

2: Basic Insights from Evolutionary Psychiatry

Two key issues emerge from the discussion in EvPs (see also Panksepp 2002, 2004):

1: *Evolutionary pressures on our forebears in the ancestral environment developed various psychological traits that are experienced by us as emotions and feelings, which then act as psychological mechanisms resulting in behaviour enhancing our evolutionary adaptation to the ancestral environment*; for example the need for reproductive effectiveness results in feelings of sexual desire that promote propagation of our genes. This is a clear statement of the causal efficacy of emotions in terms of affecting the evolutionary process.

2: *Many psychiatric disorders result from malfunctioning of these evolutionary adaptive mechanisms; hence the nature of such disorders is evidence of the nature of the underlying emotional mechanisms*. This means we can attempt to relate the major emotional systems to specific needs of evolutionary adaptation using psychiatric data as supportive evidence.

Stevens and Price emphasize in particular the pathologies that result on the one hand from failures in the *attachment system*, and secondly from the workings of the *rank system*. They state (EvPs, page 50):

> "the evidence points to the existence of two great archetypal systems: that concerned with attachment, affiliation, care-giving, care-receiving, and altruism; and that concerned with rank, status, discipline, law and order, territory, and possessions. These may well be the basic archetypal systems on which social adjustment and maladjustment, psychiatric health, and sickness depend. Both can function healthily when evoked in appropriate circumstances, but either can give rise to pathology when their goals are frustrated or when they are inappropriately activated".[5]

Both systems arise in evolutionary terms from the advantage obtained by animals operating in groups for mutual support and protection. The attachment system promotes group cohesion and mutual support; the rank system, by providing a structure to allocate resources, reduces fatal conflicts among conspecifics. In birds and mammals, the attachment system facilitates individual development and learning in relation to both the physical and social environments, particularly through parental influence. The rank system is linked to an assessor strategy that is "an algorithmic capacity that is evolutionarily stable and has been in existence since the evolution of fish and reptiles …. it enables an individual to assess whether a rival is weaker or stronger and to produce the appropriate response" (EvPs, p. 75). Subordinate animals, which might otherwise be killed, survive with the chance to successfully compete at some future point..

This evidence from evolutionary psychiatry points to the existence of ***a "hard-wired" primary emotional system concerned with social rank as an addition to the systems E1-E7 proposed by Panksepp***[6]. As far back as the earliest fish, the two most basic problems of social control were attracting mates and competing with other conspecifics for those mates (Gilbert 1989). The reproductive and ranking systems, and the affiliative system which eventually developed from the former, must have initially relied on instinctive behaviour, along the lines of Lorenz's fixed action patterns rather than emotions because components of these behaviours must have occurred in the earliest vertebrates. In evolutionary terms, therefore, the rudiments of the affiliative and ranking systems originated long prior to the existence of mammals, only later evolving into emotional systems as nervous system complexity increased. Both the affiliative and ranking systems include phylogenetically ancient structures from MacLean's "reptilean brain" (see EvPs, p. 75; MacLean 1990).

The subsequent evolution of lactation in mammals and the period of prolonged infancy in primates necessitated the later development of parental care, which then provided the basis for formation of increasingly stable social groups and a highly developed attachment system. MacLean (1990) comments that the basic differences between reptiles and mammals are 1) lactation and maternal care, 2) the development of vocal communication to maintain mother-infant contact, and 3) playful behaviour. He states, "Because of this unique family-related triad, one might say that the history of the evolution of the limbic system is the history of the evolution of mammals, while the history of the evolution of mammals is the history of the evolution of the family" (p. 247).

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[5] There is a third great archetypal system that gives rise to social adjustment and maladjustment, namely the reproduction/sex system. Steven and Price's omission of this system may be because they are conflating it with the attachment system; however we suggest these should be distinguished from each other due to their different functions, even though they sometimes work in concert.

[6] This was already suggested in AND, but possibly as a secondary emotion system rather than primary. It is also tentatively mentioned by Panksepp (1998, 2002, 2004), but not in fact adopted by him.

We follow this line of thought below by developing a systematic proposal relating emotional systems and evolutionary survival needs, incorporating the rank and attachment systems as important components.

3. The underlying propositions and criteria

The proposals we make, following the line of thought in EvPs, are based on a series of causal mechanisms summarised in the following *Theses*:

1. Emotional systems in animals are causally effective in changing behavioural patterns, in higher animals particularly through the feelings they induce.

2. Some emotional systems are more beneficial than others in terms of their effect (through this mechanism) on the capacity to survive.

3. Thus emotional systems are selected for in terms of their enhancement of survival capacity in the ancestral environment; this results in the evolution of "hard-wired" primary emotional systems, which however may be fine-tuned by early life experiences, and which then come to underlie the development of both intellectual capacities and more "soft-wired" secondary emotional systems which arise from the interaction between cognition and primary emotions (see the discussion in AND).

4. Animal survival is often enhanced by group formation, which allows cooperation, enhanced protection, group learning, and (in higher animals) evolving culture.

5. To make group membership effective, there must be both group cohesion mechanisms ensuring bonding and loyalty to the group, and mechanisms for resolving conflict and resource allocation tensions in the group.

6. The attachment system and the rank system are two major emotional systems that have evolved to meet these group needs (see EvPs). They supplement the basic systems for individual survival and for understanding and learning, and include the systems for maternal care.

7. Individual human beings experience these as emotional systems underlying psychological and developmental happenings, particularly through the feelings thereby induced, without being aware of their evolutionary origins and function.

These mechanisms are connected to each other by the way the emotional systems embodied in present day humans arise from the evolutionary imperative to meet developmental needs in the former ancestral environment, and continue to act in analogous ways today although in a completely changed environmental context. We explore the implications for the primary emotions in the next section.

Following on this, one can propose a clear set of criteria characterising primary emotional systems. A well–established primary emotion will have *all* the following characteristics:

1. *Concept:* It is identified by psychological studies as an emotion, and hence corresponds to a specific range of human feelings and associated characteristic behaviours, associated with clear eliciting stimuli that occur universally.

2. *Structure:* It is effective through neural circuitry which can be traced by electrical or chemical lesion or stimulation studies, electrical recording, and/or brain imaging , These circuits comprise distributed networks which traverse all three of MacLean's triune brain components. Each emotional circuit is integrated with the pathways of other primary emotions and each primary emotion may use components of common brainstem output pathways

3. *Function*: Each primary emotion affects the brain's functioning immediately by providing an emotional stimulus, and additionally involves a particular combination of neurotransmitters and neuropeptides, hence each can functionally take part in neural Darwinism.

4. *Development*: Although usually influenced by many genes coding for a number of information molecules, receptor sites and enzymes, nevertheless, development will be substantially genetically determined and susceptible to alteration by genetic mutation or deletion.

5. *Origin*: It can be associated with ancestral survival needs in a convincing way that is related to cladistic homologous traits (Griffiths 1997, p. 213), and hence can be clearly related to an evolutionary origin by affecting adaptive fitness.

6. *Occurrence*: It occurs universally in humans and can be associated with homologous systems in other mammals and with evolutionary precursors in lower vertebrates; this enables a correspondence of the other features listed above (2-5) between humans and our animal relatives/ forebears..

7. *Outcome*: Usually, its dysfunctional aspects can be associated with behavioural or psychiatric disorders, whose nature is either related to the missing standard function and/or disinhibition of more primitive components of its circuitry; and hence gives evidence about the nature of this function.

At the present time data are not yet available to show the presence of all these features in each emotion, however occurrence of a subset of these criteria will often be convincing evidence that a particular system constitutes a primary emotion. One key problem is to separate the primary and secondary emotions. In principle items 1, 2, 3 and 4 should be universally consistent in each primary emotional system, but not necessarily consistent for each secondary emotion. Because the secondary emotions arise from interactions between primary emotions and cognitions, they will not occur with universal consistency of structure or function.

We suggest that a good proposal can be made for a primary emotional system on the basis of occurrence of Item 1 plus any two out of Items 2, 3, and 4 (these are necessary but not sufficient criteria); it will be a strong proposal when all of Items 1-4 occur; and is indisputable if the full set of items 1-7 have been established. It is greatly strengthened if Item 5 is established, including the cladistic link; we note here that *existence* of an evolutionary explanation on its own is worth little because they are so easy to devise (Griffiths 1997), but *its absence* is a strong mark against any proposal.

4. The Relation between Needs and Emotional Systems

The primary emotions identified by Panksepp (1998, 2002, 2004; see also Watt 1999) are[7]:

E1: The SEEKING system: general motivation, seeking, expectancy.
E2: The RAGE system: rage/anger.
E3: The FEAR system: fear/anxiety.
E4: The LUST systems: lust/sexuality in the male and female.
E5: The CARE system: providing parental care/nurturance.
E6: The PANIC system: panic/separation, need of care.
E7: The PLAY system: rough-housing play/joy.

Table 1 summarises our proposed completion of this set of Primary Emotional Systems, together with the functions and relation to evolutionary needs of each system proposed.

The fundamental point is that through the evolutionary process, *each basic developmental need is matched by a corresponding emotional system that has become genetically "hard-wired" in accord with the above Theses*. Table 1 shows a plausible categorisation of the primary emotional needs that results from combining Panksepp's proposals with evidence from evolutionary psychiatry (see EvPs) and ethology.

We will consider in turn the main functional systems in this table, identifying in each case the emotions that are the psychologically effective mechanisms in terms of affecting behaviour, in the light of a consideration of the evolutionary needs of a group living in the ancestral environment (c.f. the *Theses* in Section 3). The first major grouping of systems listed relate to the functioning of the individual, and the second to the functioning of individuals in social groups.

The assumption we will make is that *it is the emotional systems in Table 1 that comprise the value system underlying neural Darwinism and thereby determining brain development* (Edelman 1998, 2001; Edelman & Tononi 2001). Thus they provide the affective valence underlying higher cognitive development (see AND).

Note that underlying the functioning of the systems discussed here are the basic sensory-motor modules involved in pattern-recognition, motor output and problem-solving that also underlie cognitive development (see Edelman & Tononi 2001 and

[7] The numbering system **E1** to **E7** is that introduced in AND. Panksepp gives his latest identification of the key brain areas and neuromodulators associated with these systems in Panksepp (2004, p. 637).

Tomasello 2003 for summaries.) These are basic in enabling the development of intellectual capacity, but we will not consider them further here.

EVOLUTIONARY NEEDS MET	**PRIMARY EMOTIONAL SYSTEM** [8]	**Works With:**	**FUNCTIONS**
INDIVIDUAL NEEDS			
Basic Functioning	**E0: Happiness/ "Liking"** (hedonic appraisal)	**E1**	Satisfying needs, reward, consummatory activity
	E1: Seeking/"Wanting" (incentive salience)	**E0**	Situation Evaluation: identifies needs, provides arousal/excitement facilitates learning
Basic Survival	**E2: Disgust system** (repulsion)		Avoiding harmful foods/ natural environments
	E3: Rage system	**E4,E9**	Defense: aggression, protection of resources, and con-specifics, limiting of restraint on movement
	E4: Fear System	**E3,E9**	Defense: flight, limiting of tissue damage
Learning	**E5: Play** system[9]	**E7,E8**	Bonding with con-specifics, development of basic adaptive and social skills, creativity
SOCIAL NEEDS			
Reproduction	**E6: Lust** system[10] (sexual desire, satiation)	**E7,E8**	Ensuring procreation, enhancement of bonding
Group cohesion: Social Bonding	**E7: Affiliation/attachment** system[11]	**E6,E8**	Creates bonding through need for others
	E8: Care/nurturance system	**E6,E7, E5**	Caring for others, particularly children
Group function: Regulating conflict	**E9: Rank** system (dominance/submission)	**E3,E4**	Controlling aggression in society, allocating resources, esp. sexual ones.

Table 1: *Evolutionary needs, and the emotional systems that have evolved to meet them. All the systems* **E2-E9** *work with* **E0** *and* **E1**, *so that dependence is not explicitly shown.*

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[8] These have been renumbered in an obvious way, as contrasted with AND, in order to suit the present scheme best. From here on in this document, this new numbering system will be used instead of the old system (which is presented above).

[9] Panksepp refers to this system as "rough and tumble play", which may describe the major component in many mammals, but in humans it also encompasses many other forms of play which facilitate learning and creativity.

[10] We separate this out below into desire and consummation systems.

[11] Labelled the Panic System by Panksepp because of the way it functions when there is separation distress; but that is not its only mode of functioning.

4.1 Basic Functioning of the Individual: Although Panksepp has referred to the basic motivational/affective system as a unitary "seeking" system, the work of Berridge and his colleagues suggests parsing basic neurophysiological mechanisms of pleasure into two separate mechanisms -- a motivational, appetitive or "wanting" system and an hedonic appraisal, consummatory or "liking" system (Berridge 2004; Robinson & Berridge 2003). These two systems can be behaviourally dissociated and function independently (Cannon & Besikri, 2004; Peciña et al. 2003; Kelley & Berridge 2002; Knutson et al. 2001). For example, electrical stimulation of the hypothalamus leads to eating but without enhanced hedonic reactions to the taste of food (Berridge & Valenstein 1991). Addiction studies also provide evidence for independence of these two systems (Robinson & Berridge 2003; Nesse & Berridge 1997).

The Happiness/Liking System E0 appears first in neonates, and must have also appeared first evolutionarily. In early prochordates consummatory responses must have existed prior to appetitive responses, with the latter arising as a way to motivate mobile organisms to pursue incentives before the hedonic impact of the incentive was experienced. Because it is ontologically and phylogenetically primary we have chosen to refer to this system as E0. The neural circuitry of this system is distributed from the hindbrain (nucleus of the solitary tract, parabrachial nucleus, probably others) through the ventral pallidum and nucleus accumbens to orbitofrontal and cingulate cortex (Berridge 2003b). Although the affective components of this system may also arise without conscious experience, happiness or contentment would be the subjective feelings associated with this system.

The **Seeking/Wanting System E1** is the primary task-oriented pathway by which affective goals are met. It is activated by primary biological needs **Di**, characterised by homeostatic signals, as well as by signals from any of the primary emotional systems **Ei**, the secondary emotional systems **Sj**, and by volitional goals $\mathbf{V_1}$ to $\mathbf{V_n}$ associated with motivational states related to specific aims ("I want to go to the movies"), each aim being characterised by a genre of intention and an intensity of desire ("I've got to drink first and then rest"). Table 2 gives a summary of these components of **E1**, which arouse, energize and motivate the organism to engage with the surrounding environment.

The physical components **Di** of **E1** represent homeostatic needs. The associated need-detectors inform the seeking system of their situation ("I am feeling tired and hungry", etc); when unsatisfactory, this activates the appetitive seeking system until satisfied, and then the consummatory system **E0** (which turns off seeking) when the need has been met. The list of physical components given here is illustrative rather than complete. There is need for a complete justified catalogue of such needs **D1-D6** (associated with "hard-wired" need detectors, presumably located in the brain stem)**.**

The other primary emotional systems **E3-E9** also feed information to the seeking/wanting system, as do the secondary emotions $\mathbf{S1\text{-}S_N}$, thereby each affecting the overall motivational state of the individual[12]. Furthermore it is through inclusion of volitional goals $\mathbf{V_1\text{-}V_n}$ in **E0** that intentions and resulting purposive action gains its

[12] It is possible that each secondary emotion **Sj** connects to **E0** via a related primary emotion **Ei**, rather than directly. Whether this is so or not will need further investigation.

emotive power: “I want that job”, “I need that house”, and so on, have an affective component. This is then the way that ethical choices and values (which are the basis on which we choose acceptable actions, for they are the topmost level of the hierarchy of goals) become effective in guiding action. They too have affective components underlying their effective power: “I want to be good”, “I hate that evil”, “I feel bad about poverty”, “I must improve the situation”, and so on. The seeking system energizes activity on the basis of need or dissatisfaction. Based in the mesolimbic dopamine pathway, it is generalised in its goals; it can be activated by any of the components of need (“I’m looking for food”, etc), but can also function in a non-specific manner (“I’m seeking something, but I don’t know what”). The associated feeling is a feeling of wanting/lack of something. One might hypothesize that negative aspects of the emotion are frustration or despair, when it seems that what is wanted cannot be achieved.

Seeking/wanting system		**Specific motivations**
Physical Components: *Biological Distress*	**D1**	Hunger
	D2	Thirst
	D3	Tiredness
	D4	Hot/Cold
	D5	Pain
	D6	Sickness
Emotional Components *Happiness/sadness aspects*	**E3-E9, S_1-S_N**	Emotional state
Volitional Components *Dimensions of Desires*	**V_1-V_n**	Chosen Goals

Table 2: *The Components of the motivational subsystems of the seeking/wanting system, which responds to specific needs. These fall into three categories suggestive of MacLean’s triune brain. The overall evaluation* **E1** *summarises the combined motivational nature of all these components.*

The **Happiness or “liking” system E0** “signals that a particular behaviour is worth doing again” (Balaban 2004), alerting the organism to the value of learning specific behaviours, and thus feeding back to the parameters of the motivational system **E1** (helping determine the kinds of things that will be wanted in the future). **E0** generates emotions of satisfaction when a desired item has been found or goal achieved, providing a reward to the organism for successful activity, and turning off the “wanting” component It is the interlocking of subcomponents of the systems **E0** and **E1** that allows emotion and intellect to work together to enable the organism to function in a purposive way.

The combination of general purpose Happiness (**E0**) and Seeking (**E1**) systems seems to provide the flexibility needed to provide the emotional underpinnings of general problem-solving purposes of the kind encountered by animals and humans. This combination of systems is proposed as a small generalisation of Panksepp's account of the Seeking system (1998), modified to take into account the work of Berridge and colleagues and Damasio's suggestion that basic emotions are built out of pleasures and pains, and motivations and drives (Damasio, 2003). The justification for this proposal is that it is a unified version of these various previous proposals, that also has the capacity to account for the emotional effectiveness of biological needs as well as of volitional choices. Any proposal made for emotional system functioning must take account of this data from everyday life.

The mesolimbic dopamine system extending from the midbrain ventral tegmental area (VTA) through the lateral hypothalamus to the nucleus accumbens and beyond has been widely taken, incorrectly, to be implicated in the neural basis of reward, (see Berridge & Robinson 2003; Wise 2004; Ikemoto & Panksepp 1999). It now appears more appropriate to consider the hedonic appraisal component of reward to be distinct from the dopamine seeking/wanting subsystem although they utilize overlapping neural circuitry. Evidence indicates that hedonic "liking" utilizes endogenous opioids, both endorphin, enkephalins and activation of both μ and κ receptor sites, as well as GABA (Cannon & Bseikri 2004; Gerrits et al. 2003; Kelley & Berridge 2002; Peciña & Berridge 2000; Van Ree et al. 2000) although dopamine may also be involved. The mesolimbic dopamine system plays a fundamental role in conditioned learning by associating arousal with specific activities, thus attaching a positive affective value to these activities, which then acts as a stimulus for their repetition. Whether or not learning involves both the Liking and Wanting subsystems is currently under debate (see Wise 2004).

Disentangling widely distributed neural systems, especially those involving biogenic amines such as dopamine, is difficult because of their interlocking functioning as well as the fact that each transmitter binds with several receptor sub-types each of which may have a different function. Indeed it may be impossible as opioids along with neurotensin (and maybe CCK) act directly on VTA dopaminergic cells. The brain is interested in integration of function, our taxonomies in parsing that functioning. For the present we suggest that the different functionalities involved justify our proposal that **E0**, **E1** should be regarded as separate systems[13].

4.2 Basic Survival of the individual. The individual requires inbuilt ways of dealing with imminent danger.

Firstly, this is in relation to the natural environment, where poisonous or infected foods or environments may threaten health. Thus the **Disgust System E2,** associated with activation in the anterior insular cortex, basal ganglia and various brainstem areas (Dalgleish 2004; Murphy et al. 2003; Phan et al. 2002), generates negative feelings leading to avoidance of such health-threatening situations. This is related to taste, smell, and feelings of nausea, but is separate from those sensations: it is evolutionarily related to the tendency to reject bitter or unwholesome foods and is aimed at preventing such feelings occurring again.

[13] It could be possible for each aspect to have a separate seeking and reward system. However this would result in a combinatorial increase of complexity because of many more causal links being needed. It is much more economical to have many systems utilising the same seeking and reward system (see Figure 2 of Berridge 2004).

Strong evidence for a Disgust system is given in the review paper by Dalgleish (2004), who gives arguments for this proposal with supporting references. Indeed he cites two meta-analyses (Phan et al. 2002; Murphy et al. 2003) that identify this system (along with the Fear system) as having the strongest evidential support. It may have originated in interaction of the emotions with the immune or gustatory systems, as an effective warning of conditions leading to illness

Key brain areas involved in disgust are the anterior insula and putamen (Hennenlotter 2004; Calder 2000) It is also very likely that nuclei in the medulla such as the nucleus tractus solitarius and area postrema play a major role. Glutamate, acetylcholine and norepinephrine are among the neurotransmitters released in the insula during conditioned taste aversion (Berman et al., 2000) and might therefore also play a role in the disgust system.

Secondly, this is in relation to the dangers created by threatening animals of the same or different species. In this case, safety is facilitated by the "fight/flight" pair of "organism defence systems": the **Rage system E3** and the **Fear System E4,** engaged when the individual perceives his/her situation as seriously threatening. The associated feelings are (as the names imply) anger and fear. These are very old systems, shared with all our vertebrate forebears (Darwin et al. 2002). Indeed, forerunners of these systems can be found in withdrawal responses and primitive versions of fear and rage throughout the animal kingdom. Which of the two solutions to threat is implemented in any particular situation is the outcome of an evaluative process based on previous experience and assessment of the present circumstances. The neural circuit for fear courses through the amygdala (this association is reviewed in Dalgleish 2004) and the hypothalamus, and utilizes the output of the PAG.

4.3 Learning in the individual. Learning, the crucial basis of all higher development, is enabled by the function of the Seeking system **E1** as the individual encounters the external physical and social environment. However it is also strongly facilitated by the **Play System E5** which in humans develops significant cortical components in addition to the diencephalic and brainstem components common to all mammals **(**Vygotsky 1978, Chapter 7; Frost et al. 2001), and this importance of play in learning is evident in many animals (Beckoff & Byers, 1998).

In mammals, play involves social aspects enabling enhanced learning, and one may suggest is facilitated evolutionarily by the enlargement of the cerebral cortex and the prolonged infant/maternal interaction which results from the development of lactation (Maclean 1990) – Play is really so powerfully rewarding (like its closely related cousin – attachment) that we will learn almost anything if it helps us to get that reward, so it must have huge ties to neuroplasticity proteins. It is an open point (and certainly a real possibility) that optimal cortical plasticity depends on the activation of play, affection, and the other rewards of close attachment. There is a ton of anecdotal information that this is the case, but the hard biology underlying this is still poorly defined. In humans, play is particularly important in language development (Bruner 1983, Chapter 3; Owocki 1999; Zigler et al. 2004; Paley 2004). This leads on to it being an essential component of much of the performing arts of the one hand, and ceremonial and celebratory behaviour on the other (often with an element of humour entailed), as well as being an important source of creativity (and so is significant also in the development of science). The associated feeling is joy/fun. Humour retains this basic tie to rough and tumble activity, including the dominance paradigms often invisibly embedded in it, in that we 'make fun' of the other, 'reducing' them in a comical way.

Learning in humans is critically enabled by the interaction with the primary care-giver in the early stages of life, the mother-child bond being the basis of such learning (also dependent on play), see Schore (1994). Thus the Care/nurturance system **E8** is also important in learning. However this may not always act in the obvious way. Parental care and in particular a caring mother-child relation will lead to much learning through the child's desire to understand the mother's intentions and the mother's desire to teach the child how to safely negotiate the world around. But in cases where there is a lack of caring attention, the child often puts great compensatory effort into learning and achievement in order to try to gain parental recognition and respect.

4.4 Reproduction. Sexual reproduction**,** enabling long-term survival of the group and the species (and thereby enabling the processes of natural selection), is the outcome of the **Sexual Lust subsystem E6A** together with the **Sexual Reward subsystem E6B** (see Table 3)**.** In the same manner as in the pleasure and seeking systems E0 and E1 the appetitive and consummatory components E6A and E6B can function independently and their behaviours can be dissociated (Pfaus, 1996).

SOCIAL NEEDS E6		***Function***
Reproduction of species	**E6: Sexual Lust system**	Ensuring procreation
	E6A: Sexual Desire	
	E6B: Sexual Satisfaction (sexual need consummation)	

Table 3: *The two distinct Components of the Lust system* ***E6.***

The associated feeling is lust/sexual desire in the seeking stage (**E6A**), and sexual satisfaction at the consummation stage (**E6B**). However, in humans, sexual desire is not simply one of the basic homeostatic urges: it is very different from the others, having a basis in a combination of conscious desires and instinctual needs, and being more fundamental in a psychological sense than any other needs - *vide* Freud's (overblown) claims, the large part of EvPs devoted to sexual disorders, and the lore of everyday life. It has a strong mental component as well as a physical one, and plays a considerable role in social bonding (but also in social tensions). Thus its workings to some degree tie into those of the systems **E7**/**E8**. This is presumably an extremely old system, but one that has changed its nature considerably in the transition to mammals and then to humans. Indeed, the evidence summarized in Panksepp's text (1998) is that evolution took sexual choice mechanisms and tweaked them to produce attachment.

This system is mediated both by hormones (transmitted through the blood stream) and also by synaptic signalling as employed by other elements of the value system

(Edelman & Tononi 2001). It can be causally effective in terms of contributing to neural Darwinism because these substances, acting either as hormones or as neuromodulators, have also been shown to affect brain plasticity. Indeed the hormonal system employed (including luteinizing hormone releasing hormone, gonadal steroids, oxytocin and vasopressin) means its influence is pervasive through the whole body, rather than just the brain domains connected to specific emotional centres through neural wiring. Oxytocin and vasopressin also function as neuromodulators in the value system associated with adult pair-bonding and parental behaviour (reviewed in Carter 2003, 1998).

Parallels exist between the Seeking system and the Sexual Lust System in as far as the appetitive and consummatory components of both systems can be shown to function independently (see above). Another parallel between with these systems is that dopamine is associated with the appetitive phase of both and endogenous opioids with the consummatory phase of both (Ikemoto & Panksepp 1999; Van Ree et al. 2000). Dopamine secretion increases as sexual arousal increases, but at consummation dopamine decreases while secretion of oxytocin and opioids increase (van Furth et al. 1995; Pfaus 1996).

4.5 Group cohesion: Social Bonding. In higher animals, social bonding and group cohesion is initially effected primarily by the **Need/Attachment System E7** in the young, leading to panic if there is separation distress, but also giving signals of satisfaction when all is well; and the complementary **Care/Nurturance system E8,** through which parents respond to signals of distress from the young**.** This is crucial in the development of those animals (mammals and birds) who depend on their parents for survival (Schore 1994; de Waal 1996, Chapter 2)[14]. Indeed children will often suffer from "failure to thrive" or syndrome of hospitalism if maternal care is not forthcoming or they will at least suffer severe psychological and/or neurological damage as in, for example Post-Traumatic Stress Disorder. The feelings in the infant are panic/distress when separation occurs, and contentment/comfort when the caregiver is near (**E7**); and tenderness/ affection in the care-giver, carrying over to reciprocal distress when the infant is perceived to be in distress (**E8**).

This then carries over to the strong adult need to be part of a social group, on the one hand, and to respond to others in a caring manner, on the other, and has for example been investigated in depth in prairie and meadow voles (Lim et al. 2004; Insel & Young 2001). In primates this interaction is characterised by the desire for *Social Attention Holding Power, or* SAHP, and results in hedonic rather than agonic functioning (EvPs pp.49-52; Gilbert 1989,1992)[15]. In primates this system became the basis of sympathy and altruistic behaviour; its neurobiological basis is discussed by Panksepp (1998) and by Insel and Young (2001), who identify oxytocin as being implicated both with maternal and adult pair-bonding. The associated human feelings are communality/ inclusion (for high perceived SAHP) and loneliness/exclusion (for low perceived SAHP). Social bonding is also supported by the sexual attraction system E6.

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[14] "Attachment … is one of the most important determinants of human well-being, and we would do well to bring it into scientific focus" (Konner 2004).

[15] In humans this is also a form of ranking, but is social ranking as opposed to the economic/political ranking that is the subject of the ranking system.

4.6 Group function: Regulating conflict. For many species, group living is crucial for survival advantage, both in terms of finding food and protection against predators (Manning & Dawkins 1998, pp.372-289; Slater 1999, pp.188-194) as well as in enabling learning. However this inevitably entails a competition for resources (Tomasello & Call 1997, p.206) that needs regulation to minimize damage to individuals as well as group cohesion. Allocation of rank (the "pecking order") occurs in animals and humans alike by various competitive processes, for example Ritual Agonistic Behaviour, thus leading to agonic behaviour that regulates this competition in a socially non-destructive way (de Waal 1996, Chapter 3; Manning & Dawkins 1998, pp.395-401; Slater 1999, pp. 200-203; EvPs, pp.49-52).

In humans it becomes embodied in social roles and associated rank, and underlies many social activities, e.g. competitive sport, as well as being fundamental in many social arrangements. Thus it becomes a central part of cultural systems.

The **Rank System E9** is the affective means employed by the evolutionary process to enable this social ranking in a way serving the interests of the group as a whole, and even the best interests of low ranking individuals by allowing them to survive long enough to compete another time. It involves a desire for higher rank, characterised by *Resource Holding Power*, or RHP, but also an acceptance of assigned status in normal conditions in human society. The associated feelings are pride/high self-esteem (for high perceived RHP) in satisfactory circumstances, and shame/low self-esteem (for low perceived RHP) when they are unsatisfactory[16].

This is a very old pre-mammalian system, the origins of which are found in instinctual behaviours patterned by the striatal complex of MacLean's "reptilian brain" (1990), but with additional limbic emotional components in mammals. Its malfunctioning can lead to well-documented psychiatric disorders (see EvPs; Gilbert 1992; Price et al. 2004) whose nature throws light on the way this system should function in a well-balanced individual. There is much evidence (e.g. Gilbert 1989) that low rank is a major risk factor for depression in mammals, as this probably indexes low probability that a host of needs will be met.

We believe the psychiatric data given in EvPs, taken together with numerous observations of animal behaviour, give sound reasons to believe that the Rank system **E9** must be recognised as a hardwired module of very ancient evolutionary origins (see EvPs: pp.47-48, 70-73). Indeed this system, characterised by Ritual Agonistic Behaviour (RAB) involving the submission subroutine, precedes the mammalian emotional system in the evolutionary schema: it is already apparent in reptiles and continues to be seen in primates and other mammals.

Panksepp (Liotti and Panksepp; 2004; Panksepp 1998, 2002) has suggested that social dominance probably arises from interactions between the childhood PLAY system and the FEAR and RAGE systems. While this may occur during ontological development of individual mammals, we propose that this system is evolutionarily ancient because dominance displays, usually related to territory and/or access to females, are found in many species of lizards, and even some fish. Social/territorial

[16] Note that *guilt* is quite different, though it is often paired to shame, as it relates to failure to live up to social or individual behavioural expectations; thus it is probably a secondary emotion related to ethical behaviour and so to ethical standards, rather than to ranking (see the discussion below in Section 5.3).

displays among male anolis lizards are associated with increased activity in the dorsolateral basal ganglia and activation patterns of these nuclei differ in dominant and submissive animals (Baxter, 2003; MacLean, 1990). The localization of serotonin and dopamine in the basal ganglia of *Anolis* is similar to primates, suggesting similar mechanisms. In squirrel monkeys lesions in the comparable area of the striatum disrupt the thigh-spread social display given by males during both dominance and courtship displays (Newman, 2003; MacLean, 1990). The striatal complex, which includes the basal ganglia,[17] constitutes a major portion of what MacLean called the "reptilean brain".

Serotonin may be one transmitter which plays a role in the RANK system, although probably only on selected receptor subtypes. Low serotonin levels have been found to be a factor in numerous psychiatric disorders including depression, suicide, eating disorders, anxiety, aggression, addiction, and obsessive-compulsive disorder (OCD) and. Serotonin may therefore play a role in decreasing impulsive, species-typical behaviours thereby stabilizing behaviour patterns by inhibition. Serotonin levels have been found to correlate with rank order in vervet monkeys; and social standing among individual monkeys has been manipulated by altering serotonin levels (Raleigh et al. 1991). Lowered serotonin levels therefore result in increased motivational drive and sensitivity to risk and reward (Allman 2000). Although serotonin (and dopamine) are both important transmitters in the basal ganglia, these neurotransmitters also seem to play a role in setting a diffuse background level of operation throughout the brain. Other neurotransmitters, neuropeptides and steroids probably also contribute to this system. For example testosterone has a modulating influence on dominance behaviours, even in humans, although it can in turn be modulated by dominance behaviours, (Mazur & Booth 1998). Furthermore both glucocorticoids and testosterone modulate serotonin turnover in the brain (Summers et al. 2000).

The link between the basal ganglia, social dominance, serotonin and OCD is intriguing and lends credence to Stevens and Price's suggestion that OCD involves a disorder of rank. MacLean originally proposed that OCD might be the result of inappropriate release of territorial and defensive motor programme fragments. The orbital frontal cortex, which plays a role in both rank (Allman 2000 p.25) and OCD (Baxter 2003), may be another area associated with this system.

In summary, we propose there is a genetically determined ("hard-wired") emotional system to do with rank, with instinctual motor components based in the basal ganglia and emotional components based in limbic structures.

5: Conclusion

The importance of correctly determining the nature of the primary emotional systems, characterised according to the criteria given in section 3 above, is that according to the proposals of Affective Neuronal Group Selection, these then determine not only the nature of immediate emotional reactions but also the details of higher level brain

[17] The putamen and caudate make up the neo-striatum with the putamen phylogenetically exploding in primate lines, in the content of the emerging need for fine motor learning mechanisms. The nucleus accumbens and globus pallidus arise from the phylogenetically older paleostriatum. This distinction has clear relationships to functional specializations of these various striatal players.

EVOLUTIONARY NEEDS MET	PRIMARY EMOTIONAL SYSTEM	Neuromodulators/ Neuropeptides	Key Components of Neural Networks
INDIVIDUAL NEEDS			
Basic Functioning	**E0: Happiness/ "Liking"** (satiation, satisfaction)	Endorphins, enkephalins, GABA (+,-), DA(?)	VTA, Nucleus accumbens ventral pallidum , brainstem nuclei
	E1 Seeking/"Wanting"	DA, glutamate, CCK (+,-), neurotensin	nucleus accumbens, lateral hypothalamus and VTA to PAG
Basic Survival	**E2: Disgust** System (repulsion)	Glutamate, Ach? Norepinephrine?	Anterior insula, putamen, lower brainstem (probably area postrema and NTS)
	E3: Rage System	substance P(+), Ach (+), glutamate(+)	medial amygdala, BNST, medial and perifornical hypothalamus, dorsal PAG
	E4: Fear System	Glutamate(+), DBI, CRH, CCK, α-MSH, NPY	lateral & central amygdala, medial & anterior hypothalamus to dorsal PAG and pontine nuclei
Learning	**E5: Play** System	Opioids (+ in small amounts, -in larger amounts), Ach	Dorso-medial diencephalon (all thalamic??) to ventral PAG
SOCIAL NEEDS			
Reproduction	**E6: Lust** System **E6A: Sexual** desire **E6B: Sexual** satisfaction	Steroids, Vasopressin, Oxytocin, LHRH (also DA, CCK?) Opioids, Oxytocin	basal forebrain, amygdala, BNST, medial preoptic and VMH to ventral PAG septum, medial preoptic (VMH in f?), VTA to PAG
Group cohesion: Social Bonding	**E7: Need/attachment** System	Opioids(-,+), oxytocin (-,+), prolactin (-/+), CRH	Anterior cingulate, BNST, POA , VTA, to PAG
	E8: Care/nurturance system	oxytocin (+), prolactin (+), dopamine, opioids(+/-)	Anterior cingulate, BNST, preoptic hypothalamus, to VTA and ventral PAG
Group function: Regulating conflict	**E9: Rank** System (dominance/submission)	Serotonin (-), testosterone (+) vasopressin (+)	basal ganglia (hypothal???) to PAG

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Table 4: *The proposed basic emotional systems together with their associated brain areas and key neuromodulators. The non-specific effects of serotonin and norepinephrine, are omitted, as are higher cortical areas. Based on Panksepp (2004), Watt (1999) and other sources. Key: PAG=periaqueductal gray, BNST= bed nucleus of the stria terminalis, VMH=ventromedial hypothalamus, VTA=ventral tegmental area; CCK=cholecystokinin, CRH=corticotrophin releasing hormone, DA = dopamine, DBI=diazepam binding inhibitor, LH-RH= leutenizing hormone*

releasing hormone MSH=melanocyte stimulating hormone, NPY=neuropeptide Y; POA=preoptic area; NTS=nucleus tractus solitarius

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functions such as cognitive modules and secondary emotions. It is important to have a *complete* list of the primary emotions, for then we know the *necessary and sufficient* variables underlying higher brain development (see AND).

The proposals we make are summarised in Table 4. The main changes proposed here from the characterisation of primary emotional systems given in AND (based on Panksepp 1998, 2002) are the proposals for

- a division of the Seeking system into **E0:** Happiness/Liking, and **E1:** Seeking/Wanting,
- inclusion of the **Disgust system E2,**
- inclusion of the **Rank system E9,** implied by evolutionary psychiatry (Price 1967) and tentatively suggested by Panksepp (1989) and Watt (1999).

It is also worth considering how our proposals relate to the classic discussions by Darwin (see Darwin, Ekman, & Prodger 2002) and Ekman (1972), summarised usefully in Griffiths (1997), and the proposals by Damasio (2003, p.44)[18]. These writings suggest that universal primary emotions are

P1. Happiness	**P2**. Sadness,	**P3**. Fear,
P4. Anger,	**P5**. Surprise,	**P6**. Disgust.

We see that their **P1** and **P2** are essentially included in our **E0**; their **P3** and **P4** are the same as our **E4** and **E3** respectively, and their **P6** is the same as our **E2**.

As commented in AND, we do not feel it is correct to label **P5**: **Surprise** as an emotion, for despite its venerable heritage in terms of study by Darwin, Ekman, and others, it does not have the same nature as the other affect programs (Griffiths 1997, p. 241), and additionally it gives no specific action guidance with survival value. Rather we believe it is an instinctive reaction. However it may well serve to urgently activate the Seeking System, and in that sense have a similar function to **E1.** Should it ever be shown to have the same kind of neural correlates as the other primary emotional systems, we would include it as another subsystem of the Seeking system.

5.1 Normative Feelings. The conscious brain is continually mediating between instinctive drives, emotional pressures, rational considerations, and ethical (normative) issues (see Figure 1)[19]. Now there is a large literature claiming that altruism derives from evolutionary processes (see Trivers 1971; Wilson 1998, 2000), and indeed is already apparent in some of our forebears, particularly primates. Thus some feelings related to what is perceived to be right and wrong, serving as the

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[18] Oatley and Johnson-Laird's article (1987) on their "cognitive theory of emotions" proposes that the innately defined set of basic emotions are Happiness, Sadness, Anxiety, Anger, and Disgust. The one that is different from those listed above is anxiety; we suggest that this is one of the possible feelings associated with the system **E0** proposed here.
[19] These aspects also interact with faith and hope, see Ellis (2004), as indicated in the Figure.

driving source for altruistic behaviour, may have an evolutionary origin and be to some degree genetically implanted in us.

This has been developed by Frank (1998) into a commitment model of emotion which includes a sense of fairness. This leads to a key question: *is there a further primary emotional system* **E10** *related to feelings of right and wrong, underlying some of our normative stances*? Or alternatively, *could such evolutionarily-derived normative pressures be reliably based in secondary emotions*? In the latter case, these would be derived from the primary emotional systems in conjunction with universal social experiences through the process of Affective Neuronal Group Selection, as set out in AND. One or other of these alternatives should hold if the arguments relating ethical behaviour to evolutionary psychology processes have any validity. This is related to work on the evolutionary value of detecting and punishing cheaters, which is probably a refinement of social cohesion mechanisms. The complication here is that it is clear that part of our ethical feelings are related to cultural circumstances – the standards that have evolved in our society and are taught us by many social mechanisms (Berger & Luckmann 1967); and part are related to individual ethical choices and understandings related to our personal experiences, often mediated by charismatic figures. Hence any evolutionary-based system will only be one of a set of interlocking causes that mediate our ethical stances.

Here it is fundamentally important to realise the distinction between a true normative system, that is ethical values providing normative standards as to what are the correct ways to behave, and emotionally based feelings as to what is right or wrong – gut feelings about how one should behave. The former (corresponding to Freud's super-ego) are a result of our overall interaction with society together with our emotions and our experientially-based reflections on social values. They have a major cognitive/ belief aspect, rather than just being a result of interactions between primary and secondary emotions, although they will be informed by these emotions. Thus there will be crucial parts of the normative system that are located in the neocortex and function as true ethical systems providing behavioural values that may well be in opposition to our emotional reactions (for example the Biblical "love your enemies" will usually collide with our emotional persuasions). It is for this reason that Figure 1 separates out ethical values from any emotional evaluations of actions.

Nevertheless the question posed is a real one: can we identify a primary emotional system **E10**: **The Normative System,** associated with feelings of right/approbation and wrong/ outrage/resentment (in relation to others) and satisfaction/guilt (in relation to ourselves), that guide our ethical behaviour? Or can we alternatively propose a path whereby such a system of feelings arises as a universal secondary emotional system, perhaps arising out of the Rank system **E9** and attachment system **E7,** in conjunction with universal experiences of disappointment when hopes or expectations are not met? Can we argue that such interactions will lead to feelings of right and wrong? (which as a simple observational fact not only clearly exist, but are very powerful emotions). It is possible that notions about conscience may just index cortical processing of these subcortical states, and secondary cognitive iterations of the primary emotions – if we are attached to others and a social milieu there are clearly rules in those attachments. A more critical way to pose this question about social rules is "what are the connections of empathy to attachment, and are they co-selected evolutionarily in some fashion" (a point made by D Watt, private communication).

Many social rules are derived from empathy and from basic mandates of attachment (we can't hurt the other too much or they will leave us). However it would be a mistake to ignore the higher level components of ethical systems and leanings: they relate to the fundamental human need to seek meaning, as commented on by Frankel and many others. (Peter Drucker, learning, language **refs**). This is a fundamental aspect of human development.

This is an important and intriguing question that merits investigation. Some resolution is needed in order to engage the literature on evolutionary bases of ethical behaviour and altruism with the proposal that neural development processes are based in Affective Neural Darwinism. However any such discussion must not be over simplistic: it must make adequate allowance for the other factors (cultural and individual) affecting ethical stances and feelings.

5.2 Implications. As pointed out in AND, the natures of the primary emotions has consequences in many areas of human behaviour. As well as taking into account as data all the professional neurology/psychiatry literature, we believe that weight should be given to the literature on educational practice which reflects a vast amount of experience of how things work in practice. Here we mention just two issues where the proposals made in this paper could have some potential impact.

Development and Education. The specific nature of the primary emotional systems underlies the development of individual minds, as discussed in AND, and hence should be a key concern in educational theory. However major texts on child development such as Bjorkland (1989) focus on cognitive and cultural issues without mentioning the affective dimension of development of the mind[20]. This is to some extent remedied in discussions on the role of play in child development (e.g. Frost et al., 2001), but the central role of emotions in development could usefully be developed further taking into account the specific primary modules identified here, particularly the hard-wired seeking system **E0/E1** together with the play module **E5**, related to creativity, as well as the rank module **E9**, related to the competitive element in education.

Rational Choice Theory. The idea of rational choice and associated utility function is central to economic theory (Simon 2001, pp.24-49). However this theory is conceptually based on purely economic concepts such as costs and revenue, not taking into account the `emotional tags' that are attached to our goals, in accordance with the discussion above. These provide a separate set of valuations affecting choice, related to the primary emotional systems, which may often override purely economic considerations. They are well-known to advertisers to be effective in motivation, particularly the lust system **E6** related to sexual attraction and rank system **E9** related to social status. However they do not seem to explicitly feature in the economic literature on choice, even though on some interpretations they might be thought of as incorporated in a hedonic vision of the utility function (Kahnemann 2000).

Our view adds weight to the proposal (Kahnemann 2000, p.761) for a distinction between *experienced utility* ("the measure of the hedonic experience of that

[20] There is a literature on emotional development and emotional intelligence in relation to education (e.g. Salovey and Sluyter 1997), but this concentrates on the important issue of the proper development of (secondary) emotion, rather than the role of emotion in intellectual development.

outcome") and *decision utility* ("the weight assigned to that outcome in a decision"). The link to what is proposed here would be made by regarding "experienced utility" as associated with the emotional pay-off attained through activation of the primary emotional systems discussed above (and perhaps partly attained through the activation of secondary emotional systems). One feature that is significant here is organisational loyalty (Simon 2001, pp.43-45), ultimately based in the attachment system **E7,** which together with any value system **E10** also underlies the `Economics of Benevolence' (Boulding 1970, Chapter 6). Another is the emotional associations of manufactured objects as described by Norman (2004), who distinguishes `visceral design', related to appearance, `behavioural design', related to the pleasure and effectiveness of use, and `reflective design', related to self-image, personal satisfaction, and images. The overall point is that the nature of the primary emotions ultimately effects the nature of economic decisions – that is, how scarce resources are allocated and used.

5.3 Further steps. Determination of the nature of the primary emotional systems is crucial to understanding the functioning of the brain, for these underlie higher level emotional and cognitive development**.** The proposals here of the nature of those primary emotions are a small step towards developing the psychological implications of AND. Clearly they need careful scrutiny. They form the basis for further development, for example considering how universally experienced secondary emotions develop on the basis of the primary emotions. Thus key further steps are,

1. Checking the *list of primary emotions* proposed here (summarised in Tables 1 to 4) for correctness and completeness: is the case for their inclusion adequate? Can they all be correctly characterised in cladistic terms? Are there further primary emotions omitted from this list?

2. Using the resulting complete list of primary emotions, modified where necessary in response to the questions above, to help determine and classify the *nature of secondary emotions*, arising out of these primary emotions via the processes of Affective Neural Darwinism.

This is part of the broader scheme of clarifying the issue of *psychological universals*. In the case of animals, Tinbergen's theory of Innate Releasing Mechanisms (IRMs, Tinbergen 1951) is such a proposal. Human commonalities and differences develop in the context of societies that have universal functional needs (Aberle et al. 1950) and physical environments with commonalities based on universal underlying physical laws (see Figure 2).

A proposed list of resulting human biological and psychological universals (Brown 1991) is given by Pinker in an Appendix to *The Blank Slate* (Pinker 2002); these might be extended to include theories such as Jung's proposal of the collective unconscious (Stevens 2001)[21]. In examining the structuring and function of the human mind, the emotional systems must be taken in conjunction on the one hand with the constellation of systems for perception, pattern recognition, and memory, and on the other the mechanisms of volition that balance rationality with the unconscious,

[21] We are aware that Jung's proposals are not popular in many quarters. However as Stevens (2001) and Stevens and Price (2002) point out, the theory of the collective unconscious is one way of describing the universal psychological propensities we inherit from our forebears – a concept fully compatible with what is being presented here.

emotion, and value systems. Understanding the interactions between these systems leads to an enhanced understanding of the evolutionary and developmental basis of emotional disorders (EvPs, see also Panksepp, 2002).

The proposals made here, based on the conjunction of Affective Neural Darwinism described in AND with the precepts of Evolutionary Psychiatry set out in EvPs, may help in clarifying this issue of human universals in a way that takes cognisance of present day neuroscience discoveries and current psychiatric knowledge, as well as data from animal behaviour and neurology. The acid test of this set of ideas would be to elucidate the many links between the prototype states and neuroplasticity molecules. Some workers are just starting to do this.

These proposals also fit into an overall understanding of how emergent complexity arises through the existence of modular hierarchical structures embodying numerous feedback control loops that process information in both bottom-up and top-down ways (Ellis 2004a). However they additionally embody two further aspects that seem to be important in the development of true complexity in the biological world. First, as proposed by Edelman (xxx) they embody the Darwinian paradigm of selection by survival of the fittest of numerous randomly chosen alternative configurations, as happens not only in the evolutionary development of plants and animals (ref) but also in the immune system (ref) and in the way protein folding takes place under the guidance of chaperone molecules (ref). Second, the way complexity arises as well as the way that information is processed in the brain is often based in a physical discretisation based in a finite number of basic elements. For example the atomic nuclei of the 92 naturally occurring chemical elements which underlie all organic complexity, are based in finite combinations of protons and neutrons, heredity is based in the four letters of the genetic code embodied in DNA, proteins are built out of 23 basic amino acids, and written language is based in a small alphabet of letters which allow expression of an almost infinite variety of thoughts. Vision is spatially discrete through rods and cones providing a division of the visual scene into pixels, colour vision is based in three primary colours, taste is based in four primary tastes, and smell is based in a large palette of discrete smells and associated receptors, Here (following Darwin) we propose in line with this theme that emotional understanding, and hence higher cognitive development, is based in the ten primary emotional systems characterised above.

Overall, the project undertaken here is supported by the growing number of studies from both the neurological and psychological sides emphasizing the role of emotions in human development. As an example, Greenspan and Shanker (2004, p.1) state "We have found that the capacity to create symbols and to think stems from what was often thought of by philosophers as the `enemy' of reason and logic: our passions and emotions .. we will show how emotions actually give birth to our very ability to create symbols and to think". This statement, based in detailed evidence on the nature of development, is fully in accord with our view on how higher cognition develops.

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Figure 1 for Affective Neuronal Group Selection: The Nature of the Primary Emotional Systems

George F R Ellis and Judith A Toronchuk

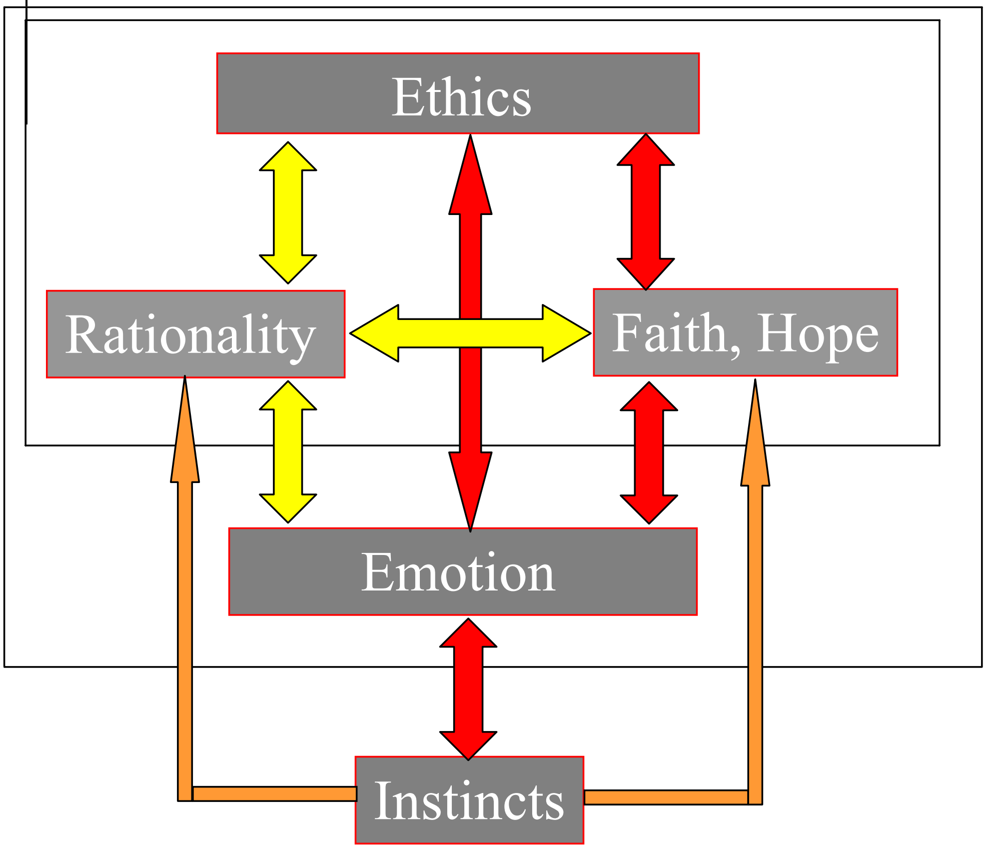

Figure 1: *Each of Rationality, Emotions, Ethics, Faith and Hope are influenced by each of the other, with reason being the key player trying to bring the others into harmony. The instinctive brain underlies this, as does the unconscious. The Figure corresponds broadly to Maclean's concept of the triune brain.*

Figure 2 for Affective Neuronal Group Selection: The Nature of the Primary Emotional Systems

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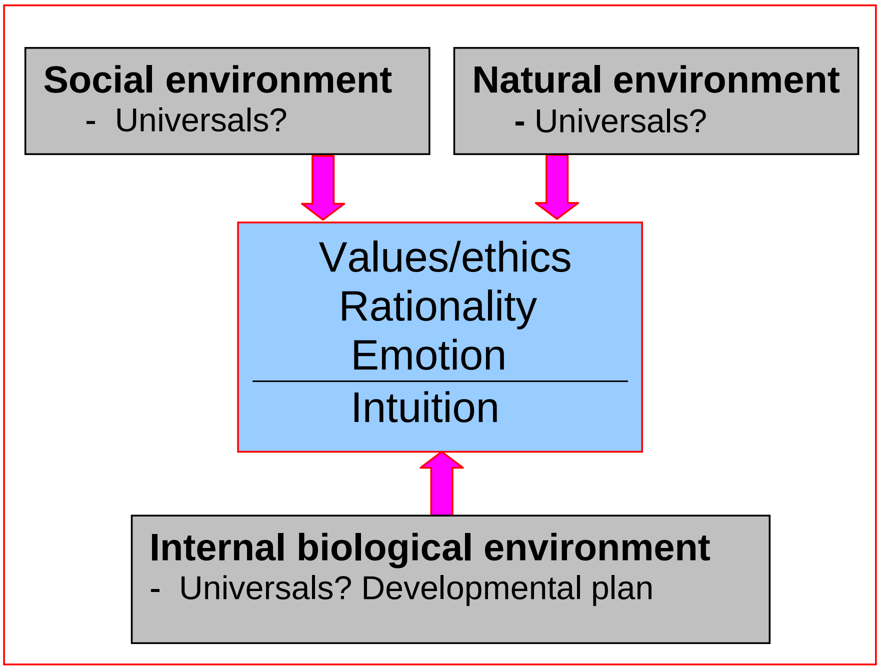

Figure 2: *Psychological universals are based on universals in the social environment, in the natural environment, and in our inherited biological makeup (underlying a universal human development plan). They all interact with each other to produce the specifics of higher brain functioning via the process of Affective Neuronal Group Selection, shaped by the primary emotions.*