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Basic Affects and the Instinctual Emotional Systems of the Brain

The Primordial Sources of Sadness, Joy, and Seeking

Jaak Panksepp

ABSTRACT

Primary-process affective processes emerge largely from subcortical action-perception brain systems that elaborate a variety of emotional-instinctual tendencies. This essay highlights how the nature of affect can be clarified by studying ancient brain operating systems that mediate separation distress, social play, and appetitive seeking in all mammals.

> No knowledge would have been more valuable as a foundation for true psychological science than an approximate grasp of the common characteristics and possible distinctive features of the instincts. But in no region of psychology were we groping more in the dark.
>
> – Freud, *Beyond the Pleasure Principle* (1920/1959)

The question "What is the fundamental nature of affect?" is one of the most important and least studied psychological question in the life sciences. If we could understand the neuro-evolutionary nature of affect, we might better understand all other forms of consciousness. Obviously such issues cannot be addressed cogently without neuroscientific strategies. Here I summarize my approach, which seeks to overlay (to *supervene*) basic affective issues onto the intrinsic instinctual emotional systems that evolution constructed into mammalian brains in "deep time" (Panksepp, 1982, 1998a). My overall aim has been to understand the nature of human affective experiences, and this approach is gaining some recognition by investigators of human emotions (e.g., Buck, 1985, 1999; Damasio et al., 2000; Solms & Nersessian, 1999). This synopsis will be largely focused on our work on the topic during the past three decades.

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THE MYSTERY OF AFFECTIVE EXPERIENCE

Since affective experiences seem to lie at the core of many of our decision-making processes, the answer to the above question is of foremost importance for the emergence of a deeply scientific psychology. Although the dynamic intrinsic processes of the brain that we call basic affects interact continuously with bodily processes and environmental events, these affects do not have to be learned, even though they are parsed and permuted further by our sophisticated, more recently evolved cortico-cognitive conceptual-analytical processes.

One of the least discussed topics in both neuroscience and the currently blossoming science of human emotions is the fundamental neuro-evolutionary nature of affective processes. Simple systematization and labeling of such processes as locations in dimensional affective space, as is so common in psychology, will not suffice for a deep scientific understanding. Modern brain imaging has dramatically advanced the field, but few recognize that such correlative approaches are not robust enough to reveal causal details.

My goal is to summarize a neuro-evolutionary approach that can resolve such issues. I frame my remarks pointedly in a psychoanalytic context that lost much of its lingering appeal following the onslaught of the neuroscience, cognitive/computational, and biological psychiatry revolutions a generation ago. I do this because Freud, in the footsteps of Darwin, sought to bring emotions, in their full glory, to the forefront of the twentieth-century intellectual agenda. Although his vision failed, at least in mainstream science, he pointed us in the right direction, as had Darwin. Modern neuroscience can now add the needed depth to our discussion of such issues; but, regrettably, investigators have generally been unwilling to regard "affect," especially as experienced by other animals, as a proper topic of inquiry. Affects are subjective experiences that cannot be directly measured, and some believe they are epiphenomena – causally irrelevant aspects of emotions that may exist only in humans (e.g., LeDoux, 1996).

My guiding premise is that affects are basic neurobiological aspects of brain organization in all mammals and perhaps many other animals. The basic affects are ancient evolved processes that helped solve some basic and universal survival problems – namely, the coding of biological values in a variable world of potential rewards and punishments. An obvious corollary of this assertion is that affects have inherited underpinnings. We do not learn to be afraid, to be angry, to be happy, to desire, and to experience pain and loneliness, even though we humans (as well as other animals) learn to whom and in which situations we should express such feelings. My overall working hypothesis is that affects are fundamental properties of rather ancient emotional/instinctual operating systems in action.

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Granted these assumptions, the best way to understand how affects emerge in human minds is to unravel their genetic and neural substrates in related animals where the detailed neurobiological studies can be conducted. As Freud put it: "Biology is truly a land of unlimited possibilities. We may expect it to give us the most surprising information and we cannot guess what answers it will return in a few dozen years to the questions we have put to it. They may be of a kind which will blow away the whole of our artificial structure of hypotheses" (1920/1959, p. 73). With a little faith in the hypothetical-deductive method, and abundant theoretically guided neurobehavioral research, we can finally look to neurobiological and evolutionary principles for a fundamental understanding of brain emotional systems and the affective states they generate (Panksepp, 1998a; Panksepp & Panksepp, 2000).

The Instinctual Action-to-Perception Substrates of Emotional Systems

Although there is no adequate taxonomy of affects, we can be confident that there are distinct varieties. Some are more integrally linked to incoming sensory processes (e.g., taste and smell), some to interoceptive drives (e.g., thirst, hunger, etc.), while yet others are more closely linked to the valenced motor-action processes of the brain (e.g., what are typically called the basic emotions), and some to the autonomic relaxations associated with the satisfaction of various drives (e.g., post-prandial and postcopulatory feelings of comfort).

My reading of the evidence is that core processes for the generation of emotional affects (i.e., fear, anger, sadness, joy, etc) are situated in ancient parts of the brain that generate instinctual-emotional action patterns – brain areas we share, with abundant neuroanatomical and neurochemical homologies, with other animals (Panksepp, 1982, 1991, 1998a). However, in clarifying these primitive sources of affect, I am in no way denying the important roles of cognitive appraisals, fantasies, and intentions in optimizing affective goals. I only wish to suggest that an understanding of the *evolved* nature of the affects will not be advanced much at the present time by focusing on those higher processes.

The most illuminating and defensible cross-species translations are bound to emerge from our detailed empirical understanding of the deep subcortical systems that all mammals share in remarkably homologous ways. My perspective is premised on the simple fact that measures of approach and avoidance affirm that the strongest affects in animals and humans are provoked by stimulating specific subcortical systems, especially those where clear instinctual-emotional behavior patterns can be aroused (Heath, 1996; Panksepp, 1985). Such effects are rare from neocortical brain regions, being largely restricted to limbic regions that are richly interconnected with the subcortical substrates of affect. One could easily

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argue that affects emerge when these primitive systems interact with neural systems that subserve higher mental activities; however, that remains an enormous and a gratuitous assumption. From the vantage of parsimony, as well as the weight of evidence, we should consider that affect arises largely from subcortical neural activities and may be a foundational process for higher forms of consciousness (Panksepp, 1998a, 1998b, 2000c, 2000d).

Few other concrete and testable ideas have been advanced concerning the neurobiological/neurodynamic nature of affective feelings. This is largely because most investigators in behavioral neuroscience have a remarkably difficult time even discussing such concepts as working hypotheses. If they actually work on emotional behaviors, they tend to wrap themselves in a cloak of terminal agnosticism and deny that such "mentalistic" concepts can be topics of rigorous scientific analysis (e.g., LeDoux, 1996, 2000). But the evidence is overwhelming – affect is a true part of neuroanimate nature, and a vigorous discussion must ensue if we truly want to understand the neurobiological nature of human emotional problems, human consciousness, and the fundamental nature of mind.

My inquiries into the nature of affect started with an attempt to understand self-stimulation reward (Trowill, Panksepp, & Gandelman, 1969; Panksepp, 1981), brain substrates of anger (Panksepp, 1971), and hunger (Panksepp, 1974). With the discovery of brain opioids, my interests turned to the study of separation distress, social bonding, playfulness, and animal laughter/joy (Panksepp, 1998a, 2000). We have also pursued work on the affective properties of a brainstem *fear command system* (Panksepp, 1971, 1990, 1996) – a view increasingly supported by subsequent research (Rosen & Schulkin, 1998). This conceptualization is usually ignored by behavioristic/positivistic investigators, who have invested mightily in straightforward classical conditioning models of information input to the higher amygdaloid reaches of this system (see LeDoux, 1996, 2000). In sum, open discussions about the nature of animal emotions are long overdue (Bekoff, 2000), especially if we wish to understand the details of evolutionarily ingrained brain operating systems that are essential for certain basic human experiences.

In broad strokes, Freud probably had it essentially right: We possess an affectively valenced nature that has profound influence over what we think and do. However, we often repress these energies and shield them from our higher cognitive consciousness. As Freud put it, "we know that the pleasure principle is proper to a primary method of working on the part of the mental apparatus, but that, from the point of view of the self-preservations of the organism among the difficulties of the external world, it is from the very outset inefficient and even highly dangerous. Under the influence of the ego's instincts of self-preservation, the pleasure principle is replaced by the reality principle." (1920/1959, p. 7).

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With the developmental maturation of the frontal lobes in humans, we develop an exquisite capacity for behavioral inhibition in the service of foresight – to reflect, imagine, and plan, with affective issues in mind – to achieve well-focused, goal-directed behaviors (Barkley, 2001). When those brain tissues are damaged, individuals begin to behave with an affective immediacy that is usually detrimental for the effective pursuit of life activities (Damasio, 1999). Indeed, various higher brain regions provide interfaces between emotional and cognitive/perceptual processes rather than intrinsically creating affect. However, limbic cortices, such as periamygdaloid, orbitofrontal, and cingulate, may well be essential for generating higher social feelings such as jealousy, envy, hate, frustration, embarrassment, shame, guilt, and arrogance. But they may only be able to do that by using more basic emotions such as separation distress and sociosexual desire as key ingredients within cognitive deliberations. Other limbic cortices such as the insula and claustrum help elaborate affective sensory feeling states such as those of taste, disgust, and pain (Chapman & Nakamura, 2001). The precise transactions that transpire in these tissues, as pursued intensively by investigators such as Rolls (1999), remains an exciting chapter of emotion research that is emerging from a straightforward behavioristic tradition.

HOW MIGHT AFFECT BE ELABORATED IN THE BRAIN/MIND?

Darwin (1872/1998) recognized three general features of emotional systems, namely, the *principle of action*, the *principle of antithesis*, and the principle of *serviceable associated habits*. He also accepted that distinct internally experienced feelings are key features of all emotions, while recognizing that those important aspects were impossible to analyze systematically with the tools available in his era. Freud was confronted by similar conundrums. The task is much easier today because the neuroscience revolution has revealed remarkable neurochemistries that help encode specific psychobehavioral tendencies (Panksepp, 1986, 1993).

Paul MacLean (1990) sought to develop an "epistemic" viewpoint in neuroscience – the study of "the subjective self and its relation to the internal and external environment" (p. 6). He argued that emotional feelings emerge largely from "limbic" circuits. Recently, his ideas (but not his vast empirical contributions) have attracted severe criticism from modern behavioral neuroscientists who disparage the many ambiguities of limbic and emotional concepts (for an overview of such attacks, see Corey & Gardner, 2002). In this combative intellectual climate, is it any wonder that so few are willing to entertain how affective processes may actually emerge from brain dynamics? Parenthetically, many of these same critics all too easily tolerate the comparable ambiguities of constructs such as the amygdala,

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which is being "extended" as we come to understand the many connectivities and functional continuities.

Besides MacLean's broad and productive limbic system concept (which pointed us neuroanatomically and conceptually in the right direction), there are three additional major lines of thought on this issue: (1) that affective feelings reflect bodily changes accompanying emotions, with a modern variant of this traditional James-Langian perspective being the "somatic marker" hypothesis by Damasio (1994); (2) that feelings are constituted somehow by "read-outs" in higher, neocortical working memory systems (LeDoux, 1996, 2000) or uniquely human linguistic abilities of the forebrain (Rolls, 1999); and, finally, the most monistic view, which I favor: (3) that affective states reflect the intrinsic neurodynamics of neuropeptidergically coded subcortical emotional-instinctual circuits interacting with the intrinsic, primordial "self-representational" structures of midline regions of the upper brainstem, concentrated in areas such as the reticular fields of the periventricular and periaqueductal gray areas (PVG and PAG), which developmentally may guide the programming of higher limbic cortices (Panksepp, 1998b).

Recently, there have been attempts to interface this last view with theories of affect such as Freud's (see Solms & Nersessian, 1999; and Panksepp, 1999b, with the accompanying commentaries). In addition, Damasio (1999b, 2000) and Buck (1999) have reshaped their views by increasingly highlighting the importance of such subcortical systems, albeit they still insist that "read-outs" into higher cerebral spaces are essential for affects to be felt. Of course, considering that emotions constitute widely broadcast "global states" of the nervous system, there is abundant room for all of these viewpoints to contribute to a comprehensive perspective. However, the critical practical issue is where best to initiate relevant analyses that can yield new findings that can be *causally* evaluated in humans. In my estimation, the neurochemical analysis of the evolved executive components will permit that better than any other approach (Panksepp, 1986, 1993, 1998a), and Buck (1999) agrees. This is not to deny that direct measurement of such processes will require direct recording of the relevant brain activities.

The neurodynamic signatures of the basic affective states are most likely to be eventually recorded directly from subcortical brain areas where distinct emotional states can be evoked (Panksepp, 2000a). I suspect that those subcortical organic processes, which provide a fundamental core representation of the organism (e.g., Damasio, 1999; Panksepp, 1998a), generate a primitive "affective consciousness" (i.e., raw feels) through a variety of emotion-specific neurodynamics (e.g., perhaps similar to those described by Clynes, 1978). It is a straightforward concept, capable of being evaluated empirically, that affect arises from the neurodynamics

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that represent the instinctual expressive character of the various emotional action systems (Panksepp, 1982). Of course, the proposition becomes highly testable in humans only when enough neuroscience details of the underlying operating systems have been deciphered, and the greatest progress so far has been made at the neurochemical level (see Panksepp, 1993, 1998a).

With the advent of modern PET and fMRI brain imaging, it is attractive to assume that higher regions such as anterior cingulate, peri-amygdaloid, insular, perirhinal, orbito-frontal, and other frontal cortical areas that richly connect with PVG and PAG areas will prove essential for everyday experiences of emotions. I personally believe that such views are partly correct. However, those compelling hypotheses are also partly negated by the fact that patients with extensive higher limbic damage still *experience* most of the basic emotions, except for disgust (Adolphs, Tranel, & Damasio, 2003; Damasio, 1999). The main deficit in such patients is a profound impairment in perceiving emotional stimuli in their environments. However, the above investigators still suspect that read-outs in cortical regions, such as somatosensory areas that represent bodily sensations (i.e., somatic markers), are essential for creating the feeling of emotions. To evaluate that possibility for myself, I have personally had rTMS brain stimulation of most of the implicated cortical areas, and regret to report that I experienced no distinct emotional experiences, although my mood was mildly affected, about as expected from prior data, during frontal stimulation (George & Belmaker, 2000). In sum, considering *all* the data, it is difficult to envision how higher neocortical areas that mediate cognitive processes could ever generate affective feelings through mere local "computation."

The existing evidence points toward the likelihood that the infrastructure of affect is fundamentally dependent on deep centro-median subcortical processes (e.g., Panksepp, 1998a, 1998b; 2000b, 2000c). This view is beginning to garner ever more support from modern brain imaging studies. Striking subcortical arousal is evident with functional brain imaging studies ranging from air-hunger (Liotti et al, 2001) to the pleasure of musical peak experiences (Blood et al., 2001), just to name a few (for more, see Panksepp, 2001a). But many higher limbic areas are also aroused. From my perspective, the functions of those higher limbic regions are largely restricted to interfacing primitive emotional functions with cognitions, memories, and plans that are related to perceptions of the external world and that permit effective regulation of emotional processes. Conversely, the subcortical affective systems imbue perceptions with feelings and thereby values (in Freudian terms, yielding the emotional *projections* and *cathexis* of ideas and perceptions).

Indeed, there is now an enormous amount of evidence that such higher brain areas are essential for the recognition of emotional sounds, stories, and facial and bodily expressions, but they contribute comparatively little

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to the *generation* of affect (although the *modulation* of affect can obviously be controlled by higher cognitive functions). These higher systems surely help organisms to regulate emotions and to learn about the affective nuances of world events (for reviews, see Lane & Nadel, 2000). However, I suspect that the historical bias against the role of subcortical, "instinctual" motor/action processes in the generation of consciousness and emotional states has been and continues to be a great barrier to progress in mind/brain science (Panksepp, 1998b, 2000b, 2000c).

Of course, definitive evidence for where affective states are elaborated in the human brain must come from the analysis of human neuro-subjectivity. Brain stimulation studies have consistently supported a primary subcortical locus of control (Heath, 1996; Panksepp, 1985). This conclusion has recently been dramatically affirmed by the Damasios. In the most comprehensive PET analysis of internally experienced sadness, happiness, fear, and anger (Damasio et al., 2000), human affective arousal was clearly linked to the activities of subcortical systems long implicated in emotional experience in animal studies, with little evidence for neocortical arousal.

An overall summary of the Damasios' data is provided in Figure 11.1. Of 189 brain sites exhibiting significant changes in blood flow, most arousal effects (i.e., increased blood flow) were found subcortically, whereas the neocortex predominantly exhibited reduced arousal (i.e., diminished blood flow). As predicted from animal work, medially situated brainstem areas were selectively aroused in all four affective states. Surprisingly, the amygdala exhibited no significant arousal except during feelings of happiness.

THE PERIAQUEDUCTAL SOURCES OF AFFECT

It seems clear that understanding the functions of tissues that surround the third and fourth ventricles, and especially the intervening periaqueductal gray matter (PAG), deserve our foremost attention in order to understand affect (Panksepp, 1998a,1998b). This brain area, in association with surrounding tegmental and tectal zones, may elaborate primary-process affective self-representation in all mammalian brains. Without that "core SELF," emotional feelings may never developmentally extend throughout the neuroaxis up to the frontal lobes.

Three compelling lines of reasoning suggest we should entertain such a radical idea: (1) It is within the PAG that we find the most massive convergence of emotional information within the brain. (2) It is within the PAG that investigators can evoke the largest diversity of coherent emotional responses with the mildest levels of brain stimulation. (3) Finally, it is within the PAG where the smallest amount of neural damage has the most severe effects on emotional expressions. Indeed, complete damage to the PAG produces a state of severely compromised consciousness (for overview, see Panksepp, 1998b).

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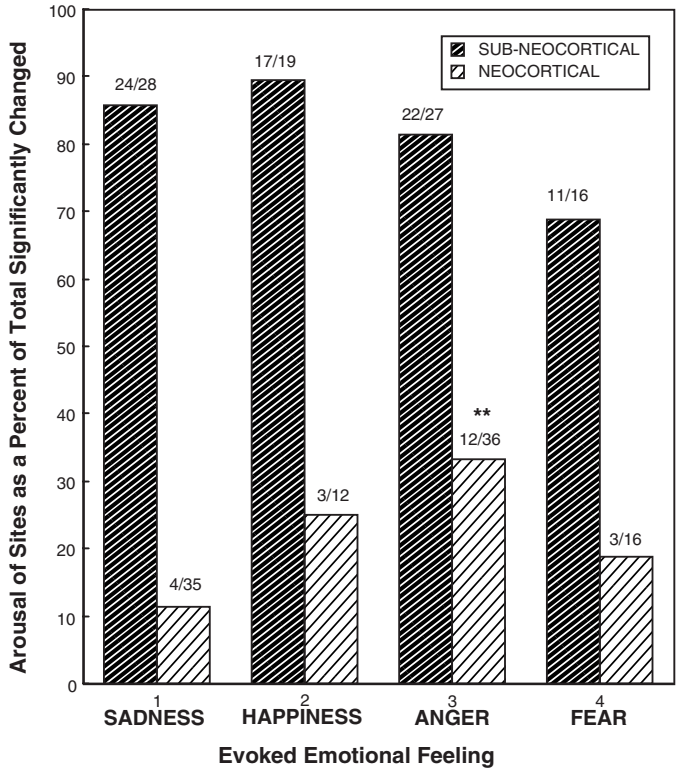


FIGURE 11.1. A summary of 189 brain sites that exhibited significant changes during four self-induced affective experiences (sadness, happiness, anger, and fear) broken down in terms of those that were situated neocortically and those that were found in sub-neocortical areas (data derived from Damasio et al., 2000).

It is noteworthy that PAG has easy access to the ascending reticular activating systems to arouse and regulate activities of many cortico-cognitive parts of the brain. The PAG has massive reciprocal interactions with the diversity of higher brain areas implicated in emotions from anterior cingulate and frontal cortices, down to amygdaloid, basal forebrain, and hypothalamic areas (Holstege, Bandler, & Saper, 1996). During infancy, human children show intense arousal of brainstem areas, but with maturation, the higher systems gain ascendancy as they become more influential in regulating behavior (Chugani, 1998). In short, the elaboration of such SELF-centered affective dynamics, through broad-scale neurochemical broadcasting of the relevant neurodynamics through the rest of the nervous system, may help establish mood-congruent "attractor basins" for perceptions, cognitions, and memories.

Such findings are remarkably consistent with Freud's view that primary-process emotionality guides the development of higher psychic functions.

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Thus, even though straightforward pleasure and unpleasure principles may directly regulate behavior during infancy, with the maturation of higher brain areas organisms develop the ability to integrate their behaviors with long-term goals, and so the immediacy of hedonic principles tends to recede into the background while still providing a long-term center of gravity for life decisions. As Freud (1920/1959, pp. 72–73) put it: "The deficiencies in our description would probably vanish if we were already in a position to replace the psychological terms by physiological or chemical ones." Surely "replace" is rather extreme ("supplement" might have been more judicious), but now a study of such supervenience relations can clarify psychological issues enormously. However, in such pursuits, we must avoid the temptations of part–whole confusions. Because psychological processes are woven of many neural components, we will never be able to reduce broad psychological constructs to singular neurological areas, systems, or processes. To minimize part–whole confusions in my own aspiration to identify essential core principles, I have chosen to use capitalizations when I label the core emotional systems.

It is incredibly important to try to identify the epicenters for affect along the neuroaxis. This is the only way we can make major progress on resolving what types of specific neurochemical systems and resulting neurodynamics we need to study in order to understand the fundamental organization of affective processes within the mammalian brain. This could be empirically achieved by contrasting the degree of affective engagement that is induced by "point arousals" at various levels of the neuroaxis – for instance, by placement of the general neuron activator glutamate into distinct areas of the brain such as amygdala, hypothalamus, and PAG, and harvesting place-preference or avoidance measures. I predict that lower areas of the brain will be more essential for affective arousal than similar stimulations of higher areas. This could also be done for any of a variety of neuropeptides: For instance, Gonadotrophin Release Hormone may be essential for certain erotic sexual feelings and urges (Panksepp, 1993), and I would predict that the place-preferences produced with this peptide (de Beun et al., 1991) are probably subcortically mediated. There is already compelling evidence for such a locus of control for endogenous opioids (Olmstead & Franklin, 1997).

The neglect of these lower "animalian" systems in the affect sciences may largely reflect the fact that so few psychologists have had hands-on experience studying them. To highlight their importance, I will now focus on three subcortical emotional systems that we have studied for the past three decades.

THE BRAIN SUBSTRATES OF SADNESS/PANIC

Our work on the nature of separation distress was initiated in 1972 with the discovery of brain opioid receptor systems. This spectacular

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finding prompted us to consider that such neurochemistries mediate social bonding. Discrete brain systems for social affect were not being actively entertained at that time. The prevailing behaviorist assumption was that such processes arise indirectly via learning experiences associated with primary rewards such as the provisioning of food, water, and warmth. Our hypothesis was based on the similarities between narcotic addiction and social dependence, which share remarkable resemblances: (1) a powerful initial pleasure-attachment phase; (2) a gradual habituation or tolerance phase in which the experienced affective pleasure from interacting with the desired "object" markedly diminishes; and (3) a traumatic withdrawal phase during enforced separation from the attachment "object."

The theory was supported by many pharmacological studies demonstrating the robust capacity of *mu* opioid receptor activity to diminish social aloneness-induced distress (SAD) vocalizations in many species, including dogs, guinea pigs, and domestic chicks (Panksepp et al., 1978a,1978b). Brain stimulation studies highlighted subcortical trajectories of the separation-distress system (Herman & Panksepp, 1981; Panksepp et al., 1988).

Of many other psychoactive agents evaluated, only oxytocin, prolactin, and glutamate receptor antagonists produced similar robust calming effects. Conversely, others such as Corticotrophin Releasing Factor (CRF) and glutamate receptor stimulants, could specifically promote separation vocalizations (Panksepp, 1991, 1998a). A diversity of other social processes were found to be modified comparably in ways compatible with an opioid theory of social affect (Panksepp et al., 1980). These findings were extended to the human clinical realm, with the still controversial opioid-excess theory of autism.

During the subsequent decade, others confirmed and extended these findings (e.g., Kalin, Shelton, & Lynn, 1995; Kehoe & Blass, 1986; Keverne, Nevison, & Martel, 1999), and it is now generally accepted that social-emotional processes are regulated by opioid and oxytocinergic dynamics within mammalian and avian brains (Carter, Lederhendler, & Kirkpatrick 1999; Nelson & Panksepp, 1998). Although a great number of details remain to be worked out, these findings provide a conceptual infrastructure for thinking about many aspects of social affect in humans. When the separation-distress system (or PANIC system, as designated in Panksepp, 1998a) is quiescent, individuals become more emotionally confident and socially dominant (Panksepp, Jalowiec, DeEskinazi, & Bishop,1985), presumably because they have a more "secure emotional base" for their life activities. With the experience of social loss, psychodynamics shift toward a panic, disposing the affective apparatus toward "painful" emotional distress that can cascade into feelings of depression and despair (Panksepp et al., 1991). The lifetime consequences of bonding quality and early attachment difficulties are profound (Meaney, 2001; Panksepp, 2001b).

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The implications of these findings for understanding affective consciousness seem straightforward. Those areas of the brain where we can evoke separation calls with electrical stimulation (e.g., Herman & Panksepp, 1981; Panksepp et al., 1988) constitute the core of the emotional "command" circuitry that generates feelings of social loss – from sadness to panic, depending on the intensity of arousal. Opioids, along with oxytocin and prolactin, released along this circuit, are brain neurochemistries that promote feelings of social comfort that accompany friendly companionship. However, such feelings, like air itself, tend to recede into the background of consciousness, only becoming affectively evident with shifts in the underlying psychochemical dynamics. Only when a sense of security is diminished by losing an attachment "object" (or a loved one) does one promptly experience the emotional dependency that arises from the affective potential of the separation distress system.

Thus, rapidly escalating glutamatergic and/or CRF or diminishing opioid activity in these systems precipitate feelings of a psychic pain, a distress that reflects an invigorated motivation to seek social companionship. When such neurochemical imbalances are rectified, social contact can again produce an invigorated pleasurable sense of social satisfaction, even joy. Since we know even less about the positive affective side of such socioemotional systems, we started to investigate the nature of the play-joy systems of the brain.

THE BRAIN SUBSTRATES OF PLAYFUL JOY AND LAUGHTER

Research on rough-and-tumble play in juvenile rats has gradually become a modest growth area in behavioral neuroscience (see Panksepp et al., 1984; Pellis et al., 1997; Vanderschuren et al., 1997). Briefly, there are intrinsic brain systems for rough-and-tumble play that generate positive affect (Normansell & Panksepp, 1990) and may have important consequences for brain development, perhaps through the genetic activation of neuronal growth factors (Panksepp, 2001b). Considering that psychostimulants commonly used to treat human children diagnosed with ADHD can markedly reduce play, I have questioned the wisdom of substituting drug treatment for the natural neurochemically mediated joys of physical play (Panksepp, 1998a,1998b). Indeed, when the PLAY systems of the brain are intensely aroused, we humans tend to exhibit a robust fixed-action pattern – laughter – that may be more prevalent among our fellow animals than has ever been suspected.

Laughter has commonly been deemed unique to humans and perhaps chimpanzees (Provine, 2000), but our work has brought that anthropocentric supposition into question. Rats exhibit robust ~50 kHz ultrasonic chirping response during play as well as during manual tickling by a human experimenter (Knutson et al., 1998; Panksepp, 2000b). We believe this

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chirping is an evolutionary homologue of primitive human laughter for the following reasons: (1) the vocalization is brought out powerfully by positive social interchange (e.g., play) and even more so by tickling; (2) all fearful and negative affective stimuli we have tested (cat smell, foot shock, new places, being held by the scruff of the neck) reduce this response; (3) individuals that chirp the most in response to tickling also play the most among each other; (4) young animals chirp more than older animals; (5) animals approach hands that have tickled them much more often than those that have petted them, and they are attracted to other stimuli that have been associated with tickling; (6) the response classically conditions rapidly to cues that predict tickling; (7) animals will learn instrumental responses to receive tickling; (8) young animals like to spend more time with older animals that chirp a lot rather than with those that chirp infrequently; (9) just like humans who are more ticklish in certain areas of the body (e.g., the ribs), young rats have "tickle skin" concentrated at the nape of the neck, where they typically direct their own play activities; and (10) the response is a temperamental characteristic of animals, for it can be successfully selected for and against within four generations of selective breeding. For details, see Panksepp (1998a), Panksepp and Burgdorf (1999, 2000, 2003), Burgdorf and Panksepp (2001) and Panksepp, Burgdorf, and Gordon (2000).

Since these results are remarkably robust and clear, we provisionally conclude that rats do, in fact, exhibit and experience a joy-laughter response. Of course, all empirical phenomena remain open to alternative interpretations, and we await major challenges to our views. Until then, we assume that, as we identify brain systems that generate this response in animals, along with the genes responsible, we may reveal the ultimate social joy principles in humans. An understanding of the key neurochemistries may yield new avenues for treating depression. Comparable possibilities exist for the other basic emotional systems.

THE BRAIN SUBSTRATES OF SEEKING

Brain research can reveal emotional systems that traditional psychological analysis has largely overlooked. The trans-hypothalamic SEEKING system, which can support vigorous self-stimulation behaviors, is such an entity. In line with prevailing behaviorist biases, these circuits were initially conceptualized as a "reward" or "reinforcement" system, which led to a large variety of paradoxes that have been extensively discussed elsewhere (Ikemoto and Panksepp, 1999; Panksepp, 1982, 1991, 1992, 1998a). My long-standing theoretical position has been that this system does not mediate consummatory reward, but rather appetitive eagerness. Such distinctions eventually led others to resolve the emerging paradoxes in the reward-pleasure concept along similar lines (Robinson and Berridge, 1993), even though they chose to focus more on the sensory/perceptual aspects

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of this system rather than on the many other attributes, such as action processes, that deserve equal attention (Panksepp, 1992, 2000c). In any event, practically everyone now agrees that this system is critical for an animal's ability to efficiently seek resources from their variable and often emotionally challenging environments (Schultz, 2001). Here I will focus on only two of the many salient aspects of this system (Panksepp, 1992).

First, to some extent the system is nonspecific, participating in the seeking of all positive resources, including the avoidance of distress (i.e., the seeking of safety). Although the arousal of this system typically has a highly energized positive affective character (i.e., a forward-looking anticipatory exhilaration that led me to originally conceptualize the system in positive "expectancy" terms), the system is also operative in many affectively negative circumstances. At the heart of this system are mesolimbic and mesocortical dopamine systems (for a comprehensive overview, see Ikemoto & Panksepp, 1999). There are many other generalized neurochemical systems of this sort – including prominently the ascending acetylcholine, norepinephrine, and serotonin systems. These systems need to be functionally/psychologically conceptualized in rather broad terms (Panksepp, 1982, 1998a), for they participate in essentially all emotional and cognitive activities ever envisioned. I find it disturbing that, recently, human psychologists are tempted to seek emotional specificity in these general state-control systems. The existence of such generalized systems should encourage us to doubt the prevailing evolutionary psychological assumption that cognitive modules exist that are architecturally "encapsulated" or "impenetrable" to other functions. Every brain faculty interacts with many others in order to operate properly, and distinct psychological functions often share many components.

Second, each emotional system is a learning system, and all learning systems operate by facilitating the salience of many relevant neuroperceptual and behavioral properties. The SEEKING system is a remarkable exemplar of this: It promotes the spontaneous capacity to seek out useful information about the world and to regulate learning. This is exemplified strikingly in the phenomenon of auto-shaping – the tendency of animals to exhibit confirmation biases where external events correlated with satisfying or unsatisfying consequences tend to be perceived as being causally related. This leads animals to behave instrumentally as if their actions could control the world, even in situations where experimenters have formally devised contingencies where no such direct causal control was physically possible (see Panksepp, 1982 and 1991 for details).

DIMENSIONAL VS. EVOLUTIONARY APPROACHES TO EMOTIONS: AFFECTIVE "SELF-REPORT" IN ANIMALS

Our work on social emotions started with the assumption that the separation calls of young animals isolated from companions could be used

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as an index of the degree of arousal of an internal emotional process that reflected their affective experience of social loss (Panksepp, Herman, Conner, Bishop, & Scott, 1978; Panksepp, 1981). Indeed, a growing number of psychobiologists now believe that we can use animal vocalizations as indexes of their affective states (Brudzynksi, 2001; Jürgens, 1998; Newman, 1988), and such measures of affective intensity may eventually be linked to popular ways of conceptualizing human emotions (Knutson, Burgdorf, & Panksepp, 2000).

Each emotional system will eventually be found to possess some type of dimensional structure, but there is not just one single form of "positive affect," or "negative affect," as is commonly assumed by investigators who are entranced by factor analytic studies of adjectives. These simplifications tell us more about how our linguistic systems operate, and how our statistical procedures extract patterns out of self-report data, than how our emotional systems were formed in the cauldron of evolution. Although there are some generalized and very primitive neurochemical systems, such as serotonin and norepinephrine, that may promote certain global moods, there are also a host of more specific neuropeptide systems that govern specific motivational and emotional tendencies. These views need to be integrated coherently, and more direct measures of affect need to be devised. We have been especially intrigued by the possibility that positive and negative valence affective measures could be devised for animals.

Recently we have suggested that ultrasonic vocalizations of common laboratory animals such as rats may be used as "self-reports" of their positive and negative affective states (Knutson, Burgdorf, & Panksepp, 2002). The 50 kHz chirp appears to reflect appetitive eagerness for many distinct rewards (Burgdorf, Knutson, & Panksepp, 2000), while the longer 22 kHz "complaints" occur in many distressing situations (Brudzynski, 2001). This strategy has turned out to be quite effective in discriminating psychologically attractive drugs from those that are repulsive (Burgdorf et al., 2001), and we are now entertaining the possibility that these vocalizations may be used as general indicators of affect, which may be especially useful in analyzing the "switch processes" that characterize drug addictions (Panksepp, Knutson, & Burgdorf, 2002).

CONCLUSION

It does seem that affective values lie at the heart of our existence as pleasure and displeasure principles around which our cognitive apparatus revolves. This in no way denies the "reality principles" that the cortex attempts to construct with its perceptual and cognitive skills. It simply recognizes that most of these cognitive skills emerge in the service of various basic needs, shared by other animals. Freud recognized how the "benevolent illusion" that rationality exists independently of our animalian tendencies prevents

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us from pursuing the deep knowledge about our human condition. As he noted (1920/1959), "The present development of human beings requires, as it seems to me, no different explanation from that of animals" (p. 50). Still, considering our great analytical and delusional skills, it is understandable why so few are tempted to head in that intellectual direction.

In sum, I would submit that it is reasonable to postulate that the basic affective feelings reflect characteristic neurodynamics that generate ancient emotional-instinctual tendencies of the body (i.e., basic "intentions in action"). This is the simplest and least dualistic way to seek an understanding of what basic emotions really are. Clarification of the neurochemistries, especially the function-specific neuropeptides, that underlie the orchestration of many basic organic "states of being" may provide the most *useful* information that we can derive from such studies. Thereby, we should be able to utilize knowledge derived from the brains and behavior of other animals to clarify the human condition and to provide new psychiatrically useful medicines. This can only be achieved by the judicious translation of such animalian neurochemical issues to human studies that seek to probe the phenomenology of affective experiences. To do that well, we will need to deploy new depth-psychological methodologies in humans (Panksepp, 1999) as well as comparable theoretical perspectives in animals. The simplest way to approach such issues is to assume that animal behavior typically does not lie, and that the instinctual emotional actions of animals do reflect the dynamics of their emotional feelings more often than they do not.

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