ARTICLE

THE LONG-TERM PSYCHOBIOLOGICAL CONSEQUENCES OF INFANT EMOTIONS: PRESCRIPTIONS FOR THE TWENTY-FIRST CENTURY

JAAK PANKSEPP
Memorial Foundation for Lost Children and J.P. Scott Center for Neuroscience, Mind and Behavior. Bowling Green State University

ABSTRACT Some of the personality characteristics of infants emerge from the positive and negative interactions of their brain emotional strengths with world events. Positive emotional systems appear to operate as attractors that capture cognitive spaces, leading to their broadening, cultivation, and development. Negative emotions tend to constrain cognitive activities to more narrow and obsessive channels. One aim of healthy development is to generate harmonious, well-integrated layers of emotional and higher mental processes, as opposed to conflicts between emotional and cognitive experiences. To understand such processes scientifically, we need to conceptualize the deep nature of the emotional brain and the psychiatric difficulties that can emerge from underlying imbalances. Obviously, one has to view the infant as a coherent entity rather than a conglomeration of neurological parts—but a scientific understanding of how their fundamental brain emotional systems may operate (based on the detailed neurobehavioral study of other mammals), may provide new ways to conceptualize how different social environments may modify those paths. Herein, I will highlight areas of research we might cultivate to promote a deeper understanding of key neuro-developmental issues. The basic premise is that with the emergence of habitual capacities to project their emotions into the world, infants gradually come to see their environments as fundamentally friendly places or uncaring and threatening ones. A great deal of this presumably emerges from brain systems that control sadness and joy. Those brain processes, along with developmental implications, are discussed in some detail.

RESUMEN: El carácter sicológico de cada infante surge de las interacciones positivas y negativas de su sistema cerebral emocional con los eventos del mundo. Los sistemas emocionales positivos parecen funcionar como situaciones que captan espacios cognitivos, lo cual conduce a su ampliación, cultivo y desarrollo. Las emociones negativas tienden a restringir las actividades cognitivas a canales más angostos y estereotipados. Una de las metas del desarrollo saludable es generar capas de procesos emocionales y cognitivos que estén integradas en armonía, en contraposición a conflictos entre las experiencias emocionales y cognitivas. Para comprender tales procesos científicamente, es necesario conceptualizar la profunda naturaleza del cerebro emocional y las dificultades siquiátricas que pueden surgir de desequilibrios subyacentes. Obviamente, uno tiene que ver al infante como una entidad coherente en vez de un conglomerado de partes neurológicas, sin embargo, una comprensión científica de cómo operan los sistemas emocionales del cerebro, basada en gran parte en el estudio de modelos animales, pudiera presentar nuevas formas de conceptualizar las rutas vitales que un individuo pudiera escoger y cómo el ambiente

Direct correspondence to: Jaak Panksepp, Memorial Foundation for Lost Children and Department of Psychology, Bowling Green State University, Bowling Green, OH 43403

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social pudiera modificar esas rutas. Reconociendo cuán escaso es el conocimiento que se basa en lo científico en esta área, y especialmente en el caso de interacciones socio-emocionales, este ensayo destaca varias áreas de investigación que se deben cultivar con el fin de promover un conocimiento más profundo acerca de algunos asuntos claves del desarrollo neural. Los efectos que a largo plazo tienen las experiencias emocionales infantiles en los animales, pudieran equipararse con procesos en los niños. La premisa básica es que con el surgimiento de una capacidad habitual para proyectar sus emociones hacia el resto del mundo, los infantes gradualmente llegan a ver sus medio ambientes fundamentalmente como lugares amigables, lugares en donde a nadie le importa nada, o lugares amenazadores de la existencia. Gran parte de esto presuntamente surge de los sistemas cerebrales que controlan la tristeza y la alegría, procesos que se discuten en este ensayo detalladamente. Las experiencias con estas emociones dejan huellas duraderas en los organismos en desarrollo. Por lo tanto, por medio de su vida emocional en los primeros años, los niños pueden llegar a ser pájaros enjaulados o espíritus libres y sensibles. Se presentan también nuevas ideas para promover esto último.

RÉSUMÉ: Le caractère psychologique de chaque petit enfant émerge d'interactions positives et négatives des systèmes émotionnels de son cerveau avec les événements du monde. Les systèmes émotionnels positifs semblent opérer comme des forces d'attraction qui capturent les espaces cognitifs, menant à leur élargissement, culture et développement. Les émotions négatives ont tendance à retenir les activités cognitives en des chaînes plus étroites et stéréotypées. L'un des buts du développement sain consiste à générer les couches interactives harmonieuses de processus émotionnels et cognitifs, par opposition à des conflits entre les émotions et les expériences cognitives. Pour comprendre de teleprocessus de manière scientifique nous avons besoin de conceptualiser la nature profonde du cerveau émotionnel et les difficultés psychiatriques qui peuvent émerger de déséquilibres sous-jacents. Bien sûr, il faut concevoir l'enfant comme une entité cohérente plutôt que comme une conglomération de parties neurologiques — mais une compréhension scientifique de la manière dont les systèmes émotionnels de son cerveau opère, basée en grande partie sur l'étude de modèles animaux, peut offrir de nouvelles manières de conceptualiser les chemins de vie que les individus peuvent choisir et la façon dont les milieux sociaux peuvent modifier ces chemins. En reconnaissant que notre compréhension basée scientifiquement demeure bien maigre, je mettrai l'accent sur les nombreux domaines de recherche que nous devrions entretenir et travailler afin de promouvoir une compréhension plus profonde de certains problèmes de neuro-développement clefs. Les effets à long terme des expériences émotionnelles infantiles sur le développement ultérieur chez les animaux peuvent trouver un parallèle dans les processus chez les enfants humains. Le prémisse fondamental est qu'avec l'émergence d'une capacité habituelle à projetter leurs émotions dans le monde, les petits enfants en viennent graduellement à voir leur milieu comme des endroits fondamentalement amicaux, des endroits indifférents, ou des endroits menaçants. Une grande partie de tout ceci émerge vraisemblablement de système du cerveau qui contrôlent la tristesse et la joie, et ces processus du cerveau seront plus ou moins étudiés en détail dans cet article. Les expériences avec ces émotions laissent des impressions durables sur les organismes qui se développent. Ainsi, à travers leurs vies émotionnelles précoces, les enfants peuvent devenir des oiseaux en cage ou ils peuvent devenir des êtres libres et sensibles. De nouvelles idées pour encourager ces derniers sont considérées et offertes.

ZUSAMMENFASSUNG: Der psychologische Charakter jedes Kleinkinds entwickelt sich auf Grund der positiven und negativen Interaktionen von dem emotionalen System seines Gehirns mit den Ereignissen der Welt. Positive emotionale Systeme scheinen als Anziehungspunkte zu wirken, die kognitive Punkte bilden, die zum Aufblühen führen und zur weiteren Entwicklung. Ein Ziel gesunder Entwicklung ist es harmonische, integrative Felder von kognitiven und emotionalen Prozessen zu entwickeln, im Gegensatz zu den Konflikten zwischen Emotionen und kognitiven Erfahrungen. Um solche Prozesse wissenschaftlich zu verstehen müssen wir die eigentlich Natur des emotionalen Gehirns und die psychiatrischen Schwierigkeiten, die aus einer zugrundeliegenden Imbalance entstehen, verstehen. Offensichtlich sollte man das Kleinkind als eine zusammenhängende Einheit sehen, jedenfalls viel eher als eine Anhäufung von neurologischen Teilen. Das wissenschaftliche Verständnis wie das emotionale System des Gehirns funktioniert, basiert zumeist auf Tiermodellen. Es könnte neue Erkenntniswege über die vom Einzelnen gewählten Lebenswegen und deren soziale Beeinflussung ermöglichen. In Anerkennung wie dürftig unser wissenschaftlich gestütztes Verstehen in diesem Gebiet sein mag, im Besonderen für sozial—emotionale Wechselwirkungen, werde ich trotzdem viele Gebiete der Forschung hervorheben, welche wir pflegen sollen, um ein besseres Verstehen mancher zentraler entwicklungsneurologischer Fragen zu fördern. Die Langzeiteffekte von emotionalen Erfahrungen auf die Entwicklung bei Tieren kann mit den Prozessen beim menschlichen Kleinkind parallelisiert werden. Die Grundannahme ist, dass es Kleinkindern gelingt, mit dem Auftreten der verlässlichen Fähigkeit ihre Emotionen der Welt zu zeigen, langsam ihre Umgebung als eigentlich freundlich zu sehen, oder als nicht fürsorgliche, oder als bedrohliche Plätze. Ein grosser Teil dieser Sichtweise kommt wahrscheinlich aus dem Gehirnsystem, das Trauer und Freude kontrolliert und diese Gehirnprozesse werden hier im Detail besprochen. Erfahrungen mit diesen Emotionen hinterlassen lang wirksame Einkerbungen in sich entwickelnden Organismen. Kinder können durch ihr frühes emotionales Leben, wie Vögel im Käfig werden, oder freie und sensible Geister. Neue Ideen das Letztere zu fördern, werden präsentiert.

抄録：乳児の心理学的特徴には、乳児の脳の感情強度と世界の出来事との陽性と陰性の相互作用から出現するものもある。陽性の感情システムは、認知空間をとらえ、それをさらに広げ、育て、発達させることへとつながる、引き寄せるものとして機能するように見える。陰性感情は、認知活動をより狭く強迫的な経路に束縛する傾向がある。健康な発達の一つの目標は、感情と認知経験との間の葛藤とは対照的に、調和的に、うまく統合された、感情とより高次の精神過程との層を作り出すことである。このような過程を科学的に理解するために、感情的脳の深い性質と基底にある不均衡から生じることがある精神医学的な問題を、われわれは概念化する必要がある。明らかに、乳児を神経学的な部分の寄せ集めではなく、むしろ一貫した存在として見る必要がある－しかし、乳児の基本的な脳感情システムがどのように働くのかについての科学的理解（他のほ乳類の詳細な神経行動学的研究に基づく）は、どのように様々な社会環境がそれらの経路を修飾するかを概念化するあたらしいやり方を提供するだろう。ここで、神経－発達上の重要な問題のより深い理解をもたらすように、われわれが育てる研究分野を、私は強調するだろう。基本的な前提は、彼らの感情を世界に投影する習慣的な能力の出現に伴って、乳児は徐々に彼らの環境を、基本的に親しみのある場所、あるいは世話をされず脅かされる場所として見るようになるということである。この大部分は、おそらく悲しみと喜びをコントロールする脳システムから生じる。これらの脳の過程が、発達上の意味とともに、詳しく議論される。

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Our children's psychological qualities are governed to a substantial extent by their emotional strengths and weaknesses. To some yet unmeasured extent, their emotional temperaments are based on ancient emotional systems—inherited brain networks that mature gradually, and often discontinuously, for many years after birth (Benes, 1994; Conel, 1939–1967; Panksepp, 1998a; Touwen, 1998), some of which remain open to being modified dramatically by traumatic experiences (Adamec, 1997; Bates & Wachs, 1994). Although we do not know the degree to which negative early experiences can permanently alter a developing child's affective temperament, a great deal of data suggests that various early emotional challenges are highly influential in guiding children's personality development (Rothbart, Derryberry, & Posner, 1994). At the same time, it is clear that to all external appearances, children are remarkably resilient in bouncing back from severe adversity (see Kagan, 1998), but the critical question must be whether those early experiences do markedly alter the quality of their inner lives.

There may yet exist undiscovered sensitive periods for neuroaffective development, similar to those that have been found in other animals, yielding life-long consequences for the emotional resilience of the child. Early emotional experiences may have life-long neural effects that modify the child's mental economy through some type of "Neural Darwinism" (Edelman, 1987). Although the study of long-term effects of different social environments on the growth of brain emotional systems has barely begun, we finally have the neuroscientific tools to detail how different experiences modify developing animal brains (Buonomano & Merzenich, 1998; Kolb & Whishaw, 1998) and human minds (Dawson & Fischer, 1994; Toga & Mazziotta, 2000). Those approaches, when applied to affective development in earnest (in naturalistic retrospective studies of human psychodynamics and prospective studies of animal behavior), should yield new insights on how we might promote mental health and vibrant lives by the way we rear our children from the earliest days onward.

I, along with many other developmentalists, believe that certain positive early emotional experiences promote optimism, resilience, and mental health, while certain negative ones do the reverse (Atkinson & Zucker, 1997; Ryff & Singer, 1998). Unfortunately the data base for such assertion is meager for our species. Although parents' psychologically tend to pass on their own strengths and flaws to their children (Danieli, 1998; Fairbanks, 1996), we do not yet know whether any of this is because of "hardware" changes in the brain. However, there is increasing evidence that such changes do transpire in animal brains. Thus, it remains a reasonable hope that devoted application of enlightened social interventions can help teach an increasing number of caretakers new and effective emotional skills and perspectives that can optimize infant development—consistent attitudes of warmth, nurturance, vigorous playfulness, along with a better recognition of how rhythmic–melodic interactions and positive growth challenges may allow brain systems to flourish and thereby to abort the cascade of adverse social-transmissions that might otherwise occur (Beebe, Jaffe, Lachmann, Feldstein, Crown, & Jasnow, 2000; Gunnar, 1998; Malloch, 1999/2000). This will not only require more and better emotional education, but a great deal more research on the psychosocial-neurobiological sides of our affective lives. Despite the empirically productive "Decade of the Brain" that just culminated, we still need an integrative "Decade of Brain/Mind Development," before we shall have a solid and useful knowledge base upon which valid prescriptions can be based.

Now that we as a society are beginning to appreciate the deep genetic and neurobiological constraints on "human nature" (e.g., Freedman, 1979; Plomin, DeFries, McClearn, & Rutter, 1998), the day is approaching when parents may have some choice over the "types" of babies they bring into the world. Of course, the fact that most of our animal dispositions have strong genetic components (Hamer, 1998; Plomin & Rutter, 1998; Scott & Fuller, 1965) will not diminish the number of hard choices we must make in the positive ways we rear our children (Goldsmith, Buss, & Lemery, 1997). Well-honed brain/mind systems can *only* emerge through the support of rich and stimulating environments (Oyama, 1985). In other words, neither the power of genetic programs nor the role of environmental input should be underestimated in psychological development (Panksepp & Panksepp, 2000; Schaffner, 1998).

Although genetic vulnerabilities in the underlying substrates are bound to have broad consequences on the physiological and affective strengths of each child (as highlighted most strikingly by gene knock-out technologies of the past decade—the so-called knock-out mice), the intra- and intergenerational effects of emotional trauma will always need to be ameliorated by life experiences no matter what additional type of assistance biological interventions may afford. There are now some well-controlled studies with other primates suggesting that maternal style can counteract emotional problems that might otherwise be expressed more intensely. For instance, constitutionally shy monkeys become more confident when reared by confident mothers (Maestripieri & Carroll, 1998; Suomi, 1997; Suomi & Levine, 1998). It is a universal principle of animal research, that animals are more tractable and cooperative if they have been well handled, well treated, and "tamed" during early development. At times, similar emotional benefits can also be promoted with drugs such as the selective serotonin reuptake inhibitors (Leonard, March, Rickler, & Allen, 1997), and eventually, they may even be promoted by administration of growth factors and more direct genetic means. However, biological interventions should only be considered as adjuncts to socio-environmental ones. Obviously, the issue of "designer children" and "cosmetic psychopharmacology" are slippery slopes that no one can negotiate with confidence.

BEHAVIORAL GENETICS: A BRAVE NEW WORLD

As I begin writing this essay, I have just finished reading a remarkable finding in this week's *Nature:* Young and colleagues (1999) report the genetic transformation of a comparatively unsocial strain of field mouse to a more gregarious temperament. This was achieved by a transgenic manipulation that elevated the number of vasopressin receptors in the brains of the rather unsocial *montane voles* to more closely resemble those of highly social *prairie voles.* A few years earlier, a converse type of psychosocial change was achieved by deleting a single gene (namely the oncogene *fosB*); such mice, when they become mothers, exhibited a dramatic reduction in nurturant tendencies (Brown, Ye, Bronson, Dikkes, & Greenberg, 1996). And now, as I am finishing this article a few months later, we are being informed that a mouse engineered to produce more glutamate receptors, of the NMDA variety, is much smarter than normal (Tang, Dub, Rampon, Kerchner, Zhuo, & Tsien, 1999). Clearly, we have entered a strange new world of possibilities.

There are now half a dozen types of knock-out mice that are hyperaggressive because of other single gene deletions (Nelson & Young, 1998), and hordes of others with behavioral profiles that have profound implications for psychiatric issues (Holsboer, 1997). At my last count (Aug. 10, 1999) there were at least 430 of such designer mice, and thousands in the pipeline, many with interesting behavioral changes that remain to be adequately characterized (Pollock, 1999). Of course, a difficulty with such models is that behavioral changes that emerge may be due to the compensatory effects that have occurred during earlier phases of development (after all, such animals have been missing the single gene in all of their cells throughout their lives). Although I do not wish to dwell on these remarkable but not yet practical findings (Gerlai, 1996; Kieffer, 1999), they do highlight the rapid advances that will emerge in our understanding of the genetic mechanisms that control emotions within the mammalian brain (Panksepp, 1998a). This type of knowledge alerts us once more to the fact that many infantile and childhood difficulties, such as autism, ADHD, and other psychiatrically significant disorders, do have genetic underpinnings. Although some of these "disorders" (e.g., such as much of present-day ADHD) may be more wisely deemed to reflect the "normal" genetic diversity of our species (Jensen et al., 1997, Panksepp, 1998b), that in no way compromises what we should aspire to achieve socially and therapeutically.

How much of this knowledge from basic genetic and neuroscience approaches will apply to humans? Conceptually quite a bit, but practically, probably rather little, at least for the foreseeable future. For practical societal consequences, we must still look to environmental manipulations more than biological ones. But because of the neuroscience revolution, we may finally understand what various environmental stressors and interventions may really be doing within the human brain. Much of our ability to think about these issues has come from the study of other animals.

MODERN DEVELOPMENTAL PSYCHOBIOLOGY AND HUMAN IMPLICATIONS

My aim here is to highlight how modern neuroscientific knowledge is solidifying our conceptions of how emotions are controlled in the central nervous system and to discuss the implications of this knowledge for the way we conceptualize key developmental issues. The recognition that affective feelings arise from specifiable neuro-emotional systems of the mammalian brain, shared across species (Panksepp, 1998a), allows us, perhaps for the first time, to begin tackling the issues surrounding emotional development in scientifically rigorous ways (Mascolo & Griffin, 1998). Thus, my comments arise not only from an acceptance of the obvious fact that the basic organizational structure of the mammalian brain is strongly constrained by genetic factors, but also from the emerging recognition that the fine details, which can have profound long-term psychosocial consequences, are highly responsive to environmental influences (Merzenich, Jenkins, Honston, Schreiner, Miller, & Tallal, 1996), including the quality of emotional relationships. Unfortunately, the holes in our scientific understanding of emotions remain large, not only in child development research where compelling long-term studies are difficult to conduct (Kagan, 1998), but also in comparatively easy areas of long-term neuroscientific studies utilizing animal models.

At present, there are regrettably few lines of hard evidence concerning the long-term "fertilizing" influences of positive socio-emotional environments on either the brain or psyche. By comparison, the untoward consequences of impoverished environments on brain development are vast (Kolb, Forgie, Gibb, Gorney, & Rowntree, 1998; Rosenzweig & Bennett, 1996). Also, the influences of nutritional-energetic ones are well studied in many species (Desai & Hales, 1997; Henry & Ulijaszek, 1996; Morgane et al., 1993; Mouseseau & Fox, 1998). Likewise, neurotoxicological approaches have received much attention (Slikker & Chang, 1998), especially the many long-lasting effects of commonly used recreational drugs on the nervous system (McCann, Lowe, & Ricaurte, 1997).

There is now an enormous amount of developmental brain research that has been conducted strictly from neuroanatomical, neurochemical, and neurophysiological perspectives, commonly driven by technological breakthroughs rather than by coherent questions about the emergence of adaptive developmental landscapes. Unfortunately, the majority of existing works have few immediate consequences for infant mental health issues, although they provide abundant food for thought as well as fuel for worry. Some of my recent favorites from a prominent journal that publishes a great deal of such work include (a) the effects of environmental "enrichment" on specific neurons in the brain (Fernandez, Bravo, Sanhueza, & Inzunza, 1998), (b) the long-term facilitatory effect of amphetamine on brain norepinephrine activity (Nasif, Cuadra, & Ramirez, 1999), and (c) a documentation of how certain types of brain damage just prior to birth that have more severe developmental consequences than those inflicted soon after birth (Villablanca, Carlson-Kuhta, Schmanke, & Hovda, 1998).

Of course, many manipulations in such animal studies are so intrusive that the relevance for practical human issues remains uncertain. Also, the application of knowledge can lag discoveries for a very long time. For instance, the growth factors that have been discovered in the brain that will have direct implications for human brain development are numerous (Finkbeiner, 1996), but it will be a while before that type of knowledge will be capable of being deployed for the treatment of serious developmental disorders. Fortunately, there is some evidence that life activities, like sensory stimulation and motor exercise, can modify some of these factors in beneficial ways (e.g., Rocamora, Welker, Pascual, & Soriano, 1996), and those interventions already have potential practical consequences, as in the treatment of autism and ADHD (Panksepp, 1998b). Thus, although the lines of evidence that are unambiguously relevant for understanding normal and abnormal emotional developmental remain modest, I will attempt to gaze into that hazy crystal ball in this essay.

Philosophically, I write this essay from the perspective that the future of humanity will continue to be shaped substantially by the emotional character of our children. Because of their enormous resilience and plasticity, most children will thrive in a variety of environments, with no systematic interventions. But, as I will repeat like a mantra, *there is every reason to believe they will emerge with different emotional strengths and weaknesses depending on the emotional environments in which they have lived.* Early emotional experiences can have life-long consequences within the internal affective texture of individual lives, even though there may be little to be observed in obvious short-term external behaviors. Now that we are beginning to formulate new concepts for promoting positive human health (e.g., see Mayer & Saper, 1999; Ryff & Singer, 1998; Seligman & Csikszentmihalyi, 2000) and to understand how powerfully emotionally negative environments, especially early social loss, can detrimentally impact long-term psychological development (Kendler, Kesler, Neale, Heath, & Eaves, 1993; Silove, Manicavasagar, Curtis, & Blaszczynski, 1996; Westenberg, Siebelink, Warmenhoven, & Teffers, 1999), we may need to fine tune and at times reconceptualize the kinds of optimal growth environments we should be constructing for our children.

My personal sociological view is that our present culture, despite its materialistic richness, has some deep spiritual cavities—psychogravitational black holes, if you will, that are pulling our quality of life into a slow decline, at least with regard to the emotionally positive humanistic and spiritual values that should ideally constitute the core of any healthy society. The escalating numbers of imprisoned individuals and the growth of devastating childhood violence, pervasive addictions, and impulse control disorders of sundry sorts that arise from excessive self-centered egotism and narcissism are the surface symptoms of those trends. Although these are complex and perhaps unsolvable societal problems (especially if we accept the “dark” sociobiological underpinnings of social systems, where all too much of social behavior seems to be based upon selfish kin selection and other forms of inclusive fitness—Buss, 1999), they are, in part, related to the ways that we emotionally rear our children. The human species, because of its massive general-purpose cerebral endowments, has choices that other species, who are more tightly constrained by primitive kin selection mechanisms, cannot imagine (Panksepp & Panksepp, 2000). The overriding viewpoint of this essay is that our children might grow up better if we, as a society, were better informed about the psychobiological and emotional substrates of the human spirit (Konner, 1982; Panksepp, 1998a; Schore, 1994). If we were more willing and able to allow our youngsters to openly appreciate, experience and thereby deeply understand the full richness and dynamics of the emotional potentials they inherited, we might have a better society. For instance, we must come to terms with the desire of our children to really play in rough-and-tumble ways (an ADHD symptom?)—and to dance vigorously and play heartfelt music—and then to try to determine empirically what such activities do for brain/mind development (Panksepp, 1998b). Thus, my main concern here will be with brain issues that may impact on the long-term emotional development of our children.

GENERAL COMMENTS ON EMOTIONAL ENVIRONMENTS AND PSYCHOLOGICAL CHANGE

In general, my assumption, presumably not controversial but certainly unproven, is that different early emotional experiences can lead to different life trajectories (e.g., Boris & Zeanah, 1999; O'Connor, Bredenkamp, & Rutter, 2000). I will develop the idea that the epigenetic topographies of individual lives emerge from the ontogeny of various genetically coded emotional systems of the brain that provide the basic psychological birthrights and developmental springboards for each newborn's mind. However, these gifts of nature can unfurl ontogenetically in many different ways, depending upon the psychological structures and dynamics of the living environments in which children find themselves. The question of exactly *What develops in emotional development?* must become an even more active area of psychological inquiry than it has in the past (Mascolo & Griffin, 1998).

A great deal of the rigorous data for this thesis must come, by necessity, from animal models. Although the pertinence of such lines of evidence could easily be questioned in earlier days, the accumulated knowledge now suggests many homologies in the underlying neuropsychological structures, especially the subcortical ones that mediate basic emotional urges, abound across all mammalian species (Panksepp, 1998a). Indeed, developmental brain imaging data suggests that infants psychologically experience their lives in subcortical realms much more than in cortical ones (Chugani, 1996), but the higher areas rapidly gain ascendancy, with cerebral maturation continuing well into the second decade (Benes, 1994). Unfortunately, our ability to conceptualize basic psychological processes in neural terms has only emerged recently, and we are still in the midst of trying to sift basic from derivative processes. We already know how dramatically certain components of the brain develop and change as a function of early experiences (Dawson & Fischer, 1994; Hann, Huffman, Lederhendler & Meinecke, 1998). However, all too often the neurological changes remain to be psychologically characterized, and the psychological changes have few neurological referents. Also, there will be many unanticipated complexities, ranging from different gender-specific and brain-specific effects of environmental experiences at different ages (Kolb et al., 1998) to the consequences of distinct family environments (Laviola & Terranova, 1998).

Despite remarkable advances in neuroscience and psychology during the past few decades, our attempts to relate core psychological processes to neural processes remains rudimentary. As Solms and Nersessian put it (1999, p. 91, their emphasis): "*A psychological model only becomes accessible to physical methods of investigation once the neural correlates of the component of the model have been identified.*" Although we now recognize many of the neural components, there is presently remarkably little evidence how either the neural substrates or the psychobehavioral manifestations of specific emotional systems change as a function of developmental experiences, especially in humans. We do know that a single traumatic emotional experience can have long-term psychological and bodily consequences in children (Pfefferbaum, 1997; Siegel, 1997). In adult animals such effects can often be reversed dramatically by the mere availability of friendly social contacts (e.g., Ruis et al., 1999). Indeed there is now considerable knowledge of how different social environments modify the developmental trajectories of young animals (Laviola & Terranova, 1998), and recently there has been a special focus on maternal influences (Fleming, O'Day & Kraemer, 1999; Francis, Diorio, Liu, & Meaney, 1999; Maestripieri, 1999). The power of the intrinsic social processes of the brain were, until recently, greatly underestimated in brain research (for overview, see Panksepp, 1998a). Thus, as already noted, the amount of evidence for negative stress-fear factors on brain development is enormous, but studies on the influence of positive factors, despite a prominent literature on so-called "enrichment," remains modest.

A FEW REMARKS ON EXPERIENCE-DEPENDENT BRAIN PLASTICITY

The fact that environmental *impoverishment* in animals can markedly reduce brain growth and psychological development has long been recognized (e.g., Greenough, 1987; Rosenzweig, Bennett & Diamond, 1972; Rosenzweig & Bennett, 1996) with some remarkable recent elaborations (Kempermann, Kuhn, & Gage, 1997; Kolb et al., 1998), including the ability of psychosocial stress to reduce hippocampal plasticity (Gould et al., 1997). Unfortunately, the findings in this prominent research area have commonly not been as frankly discussed as they should have been. I chose to reverse the traditional description of this phenomenon, which is usually described in terms of the positive effects of "enrichment." I do this because the individually housed animals of the control groups in all too many of these experiments are really receiving the more significant interventions than the experimental groups: under natural conditions animals would presumably grow up in even richer environments than the supposedly "enriched" animals of such experiments. Accordingly, to be quite forthright about the matter, we should typically interpret those studies as highlighting the dire consequences of impoverishment rather than of enrichment. Indeed, the severe consequences social impoverishment or "hospitalism" have long been recognized in human babies since the groundbreaking work of Spitz (1965), and continuing to the modern day (O'Connor et al., 2000).

Accordingly, the above analysis provides a cautionary dimension when we consider the utility of animal data from "enrichment" experiments for better understanding the factors that may benefit human development. Enrichment and impoverishment are relative terms that ultimately refer to the socio-ecological *status quo* of the species under study. Most of our kids are already quite materially enriched, and it is unlikely that their brain growth/maturation could be facilitated substantially by additional opportunities in those realms. The types of enrichment we should now attempt to evaluate are ones related to emotionality, general spiritual values and the arts. Such issues, which can be encapsulated by the term "emotional education" deserve more attention in early child development than they have yet received (Goleman, 1995).

In any event, modern neuroscience now offers great hope that true enrichment (playful and joyous) and extra exercise with the various aesthetic faculties, may have substantial effects. The number of growth factors and neuronal guidance molecules that have been found in the brain, most of which are probably responsive to environmental stimulation, is enormous (Finkbeiner, 1996; Strittmatter, 1995). The evidence for a key role for brain glutamate transmission in such dynamic plasticities is impressive (Anwyl, 1999, Constantine-Patton, 1998). The ability of neural circuits to be molded by experience, within substantial genetic constraints, is vast including the facilitation of "enrichment" induced neuronal proliferation within certain areas such as the hippocampus (Kempermann et al., 1997). Thus, the ability of early emotional experiences, perhaps even mild negative ones, to have important positive consequences on children's lives remain a tantalizing possibility. In this context, we might also wish to recall that the domestication of animals, with all of the ensuing behavioral effects (Price, 1984; Trut, 1999), has led to about a 5% overall decrement in brain size (Kruska, 1987).

Unfortunately, the amount of incisive behavioral neuroscience work that has practical consequences for molding developmental processes remains modest. This may be because neuroscientists have been rewarded by prevailing funding practices for ignoring the types of integrative emotional issues that might have the most practical impact on child health issues. In my estimation, the questions that have the clearest potential for elucidating how different sensory and social environments can modify emotional integrative systems of the brain remain largely unstudied. However, when such integrative research begins to be supported, we should try to avoid the flaws that have characterized previous work along such lines—one of the worst being the funding-policy induced disinclination of neuroscientists to conceptualize any brain functions in emotional terms. As a result, there are still many exceptional, rigorously minded behavioral neuroscientists who claim their animal subjects do not experience emotions (e.g., LeDoux, 1996; Rolls, 1999), which is probably not only wrong but is bound to be deemed immoral by many.

For basic neuroscience to have major impact on infant mental health issues, it must come to terms with many psychologically relevant integrative functions of the brain. Unfortunately, this has been a slow and tortuous progression, and only recently are there signs of a major coalescence of ideas into conceptual schemes that can provide insightful future experiments (Panksepp, 1998a; Schore, 1994). The recognition that neurochemically characterized circuits, such as neuropeptidergic ones, may modulate specific emotional tendencies has great potential for evaluating discrete structure–function relationships (Panksepp, 1993a, 1998a). In any event, my aim here will be to briefly highlight beneficial directions that such work may take, with much of my focus being on the insights that might be obtained from a greater investment in the study of emotionally relevant neurodevelopmental processes in experimental animals. Although most of what I have to say will be related to emotional issues, I proceed with the recognition that emotional and cognitive abilities have coevolved in higher regions of the brain, along with the supposition that a better appreciation of distinct affective and cognitive processes, perhaps even such distinct forms of consciousness, may need to be recognized within the psychological economy of mammalian brains (Panksepp, 2000b).

Because emotionality is remarkably ancient in brain evolution, there is every reason to believe that the underlying brain systems served as a foundation for the emergence of basic social and cognitive abilities. The basic emotional systems of the brain imbue environmental events with values (i.e., "valence tagging"), and deficiencies in emotions may lead to psychiatric problems characterized by distinct cognitive and social idiosyncrasies. In developing infants such processes may be psychologically decisive. Infants may fundamentally project their emotions into the world, and initially assimilate cognitive structures only in highly affective ways. Through such egocentric assimilations, the emerging cognitive structures may gradually come to feed back and to regulate the emotional systems. The rich interpenetrations of emotions and cognitions establish the major psychic scripts for each child's life. Some of those early imprints may last a lifetime—often in ways that lead inexorably to future psychological problems (Atkinson & Zucker, 1997; O'Connor et al., 2000). In any event, it seems that the essential role of emotional systems in brain development have been vastly underestimated.

At times, especially in the realm of emotional dispositions, biology does constrain destiny. In general, the neurological "Kennard Principle," which asserts that recovery of function following early brain damage will be more dramatic than the same injury in adulthood, is only well documented for some of the higher brain functions (e.g., cortico-cognitive abilities). Just the reverse is commonly true when damage occurs within the basic subcortical and limbic cortical operating systems that mediate emotions and motivations (Panksepp, 1998a). For instance, the types of social changes that result from brain damage in adults (e.g., the decline of social sensitivities following prefrontal cortical damage) lead to very similar permanent changes when they occur in during infancy, and such changes are not compensated during development (Anderson, Bechara, Damasio, Tranel, & Damasio, 1999). Parenthetically, it is worth noting that the types of frontal cortical neural changes that are observed in adults (Davidson, 1992) are also evident in infants, especially in response to maternal separation (Davidson & Fox, 1989; Dawson, 1994). Indeed, there is every reason to believe that infants and young children feel emotions more intensely than adults albeit for mercifully shorter durations. What emerges mostly during development is the higher capacity to regulate emotional states and to construct more complex behavioral strategies to cope with emotionally challenging events.

Although socially constructed emotional expressions emerge from higher cortical areas, sincere emotional expressions emerge from subcortical systems (Rinn, 1984). It is the subcortical systems upon which infants rely upon most for survival and presumably their initial psychological lives. To understand infant psychology and its disorders, we must come to terms with those deep (i.e., subcortical) and fundamental emotional systems of their brains. This, in no way, is intended to minimize the importance of higher cognitive processes in normal or abnormal emotionally tinged cognitions (Borod, 2000; Broman & Grafman, 1994; Zelazo & Barr, 1989), but to emphasize the critical role of more primitive brain emotional command systems in guiding normal development and the emergence of emotional disorders.

TOWARD A NEW TAXONOMY OF PSYCHOPATHOLOGY—A FOCUS ON EMOTIONAL CIRCUITS

When an infant is born, its internal life presumably revolves around basic emotional and motivational issues that reflect the genetically ingrained aspects of its nature—the types of processes that would have been considered "drive" and "id"-related functions in classic psychoanalytic theory. From the emotional perspective, prevailing birth practices that still include extended separations of the infant from the mother soon after birth, routine use of cruel practices like circumcision, the absence of abundant physical contact with others, and excessive feeding from bottles as opposed to breasts, can be deemed remarkably shortsighted. Most of those ill-informed practices were (and still are) based on the faulty assumption that infants do not experience emotions, that their cries and smiles are simply primitive affect-free reflexes. Now we are beginning to recognize that infants do feel and perceive intensely (Anand, 1997; Blum, 1993; Lindh, Wiklund, & Hakansson, 1999), even though they, like other animals, obviously have a rather impoverished cortico-cognitive understanding of what their feelings are all about. Still, with the immediacy of their ingrained emotional processes, which generate "intentions in action" (Panksepp, 2000b), infants are quite capable of responding affectively to caretakers (Cohn & Tronick, 1983; Termine & Izard, 1988), and thereby molding their behaviors in adaptive ways (Lucas & St. James-Roberts, 1998).

Newborns can make sophisticated emotional choices. For instance, they are attracted to and soothed by the smell of amniotic fluid (Varendi, Christensson, Porter, & Winberg, 1998), and they can be comforted by the mere presence of their mothers' nightgowns (Sullivan & Toubas, 1998). Also, human babies become rapidly devoted to their mothers' lilting voices (Fifer, 1987), while exhibiting little affinity for their fathers' more sonorous tones (Ward & Cooper, 1999).

Now that we recognize that all young mammals have specific separation distress systems in their brains (Panksepp, Normansell, Herman, Bishop, & Crepeau, 1988), we need to determine how different social environments modify the developmental maturation of the underlying emotional systems (Gunnar, 1994). Chronic overactivity of such brain systems may lead to feelings of sadness, alienation, and probably the development of constitutional tendencies for chronic feelings of shyness, guilt, shame, and depression (O'Connor et al., 2000; Schmidt & Schulkin, 1999). Regrettably, because of funding-policies there is still very little basic neuroscience work on such key topics, even though the psychobiological foundations for such ideas were laid down many years ago (Panksepp, Herman, Conner, Bishop, & Scott, 1978; Panksepp, Herman, Vilberg, Bishop, & DeEskinazi, 1980, Panksepp, Siviy, & Normansell, 1985).

At a slightly older age, heralded by the onset of infantile laughter, specific play systems come into the overall developmental equation. As I will discuss in some detail, the continuing practice of not giving young children abundant access to the natural social play of our species, may be having untold consequences on the evolution of our cultural fabric (Panksepp, 1998b). The possibility that extra rough-and-tumble play and tickling can be effectively used in therapeutic contexts deserves more attention than it has received (Panskepp, 2000c).

There is presently little question among investigators that some children are born with variable personality potentials (Freedman & DeBoer, 1979)—some being very resistant to hardships while others are more easily harmed (Gunnar, 1998). We must now empirically detail how protracted early experiences with various emotions impact on the subsequent long-term psychobiological development of infants with differing genetically provided temperaments (Schmidt & Schulkin, 1999). Most of the incisive scientific work will have to be done with carefully selected animal models, and we have to seriously consider that developmental patterns that emerge across several species may generalize to humans (Lopez, Akil, & Watson, 1999). In any event, we can expect that most children will exhibit great resilience to adversity, while others may not. Depending on their early experiences, *all* may change the ways they affectively deal with the world for the rest of their lives. At present, a most compelling case for human children can be made for the long-term effects of early sadness and anxiety (Chorpita & Barlow, 1998; O'Connor et al., 2000; Westenberg et al., 1999), and key brain substrates for those responses have been provisionally defined (Panksepp, 1998a). We now need to detail the neural underpinnings of chronic emotional changes, for that is the type of information on which psychiatric diagnostics and therapeutic prescriptions must eventually be based.

Although the traditional DSM-IV categories can be effectively utilized in developmental psychiatry (Harris, 1995), there is substantial room for conceptual development (Jensen & Hoagwood, 1997), especially when we actually begin to consider the role of specific emotional systems of the brain. This can be done in two general ways. It can be based on our recognition that certain broad-ranging psychobiological emotional control systems, created from complex multidimensional circuitries, are the birthright of every infant's brain. Conversely, it can be based on the recognition of very specific brain circuits, based on amino acid transmitters, biogenic amines, and a large array of neuropeptides that have specific roles in governing various psychobehavioral abilities (Panksepp, 1993a, 1998a). The conjoint utilization of both perspectives will ultimately be the most effective basis for psychiatric diagnostics in the future. Of course, at present, the main difficulty in using the emerging neuroscientific knowledge systematically is our inability to routinely measure the ongoing operations of such systems in the human brain. Despite massive progress in our ability to image brain functions (Thatcher, Reid, Lyon, Rumsey, & Krasnegor, 1996; Toga & Mazziotta, 2000), including emotional ones (Mayberg & McGinnis, 2000), the visualization of specific neurophysiological and neurochemical activities, remains an ideal to be aspired toward.

Fortunately, the emotional systems that have been identified in animals (Panksepp, 1998a) correspond nicely to what are widely deemed to be basic emotional systems (affect programs) in humans (Buck, 1999; Tomkins, 1980). As indexed by facial expressions by six months of age human infants already express most of these emotional attitudes (Lewis, 1993). Based on such brain systems, we can roughly envision what future diagnostic systematics might look like. Following on earlier suggestions (Panksepp, 1982, 1988), Table 1 highlights how abnormal activities of basic emotional systems and major psychiatric categories may be interrelated.

Of course, the above is only a skeleton schematization of the most robust relationships, but it does suggest diagnostic avenues that have been neglected. For instance, it would seem that separation anxiety disorders (SADs) may be presently underestimated (Silove et al., 1996). Many of the "emergent emotions" that arise from developmental processes (middle column in Table 1), may deserve more emphasis in psychiatric systematics.

It cannot be overemphasized that the basic emotional systems may developmentally be like dynamic system attractors that get larger, more complex and more sophisticated as they pull various cognitive structures into their spheres of influence. As a general principle, the larger the sphere of influence of the positive emotions, the more likely is the child to become a productive and happy member of society. The more he or she is influenced by negative emotions, the more the paths toward unhappiness are paved. There is every reason to believe, albeit rather little data to share, that such systems are molded during early development by

TABLE 1. *Postulated Relationships between Basic Emotional Systems, Common Emotional Processes, and Major Psychiatric Disorders*

Basic Emotional Systems (See Panksepp, 1998a)	*Emergent Emotions*	*Emotional Disorders*
SEEKING (+ & −)	Interest Frustration Craving	Obsessive/Compulsive Paranoid schizophrenia Addictive personalities
RAGE (− & +)	Anger Irritability Contempt Hatred	Aggression Psychopathic tendencies Personality disorders
FEAR (−)	Simple anxiety Worry Psychic trauma	Generalized anxiety disorders Phobias PTSD variants
PANIC (−)	Separation distress Sadness Guilt/shame Shyness Embarrassment	Panic attacks Pathological grief Depression Agoraphobia Social phobias
PLAY (+)	Joy and glee Happy playfulness	Mania ADHD
LUST (+ & −)	Erotic feelings Jealousy	Fetishes Sexual addictions
CARE (+)	Nurturance Love Attraction	Dependency disorders Autistic aloofness Attachment disorders
The SELF—a substrate for core consciousness (see Panksepp, 1998c)	A mechanism for all emotional feelings	Multiple personality disorders?

The last two columns only provide best estimates of the major relationships. Obviously, multiple emotional influences contribute to each of the emergent emotions (e.g., jealousy is also tinged by separation distress and anger), and all the emotional disorders have multiple determinants. Plus and minus signs after each indicate major types of affective valence that each system can presumably generate.

Capitalizations are used to designate the various emotional systems to highlight the fact that these are instantiated as distinct neural entities rather than simply psychological concepts. The essential neural components constitute command influences that coordinate the basic behavioral, physiological and psychological aspects of each emotional response.

various life experiences. Many investigators believe neuroscience data will eventually clarify how such negative and positive paths can be strengthened through early influences (Lopez et al., 1999), but that will require a new era of integrative behavioral brain research.

Each of these emotional systems presumably follows straightforward psychological laws, that remain to be experimentally delineated, but which will have profound implications for developmental issues. For instance, a great deal of extraversion and introversion probably rides on the vigor of the various underlying emotional systems (see Depue & Collins, 1999, and commentaries). Because each infant's primary sense of self is probably more fundamentally emotional than cognitive, let me briefly share some straightforward thoughts for those primary emotional system that has been revealed through neuroscientific approaches discussed thoroughly in Panksepp (1998a). These principles are by no means novel, but practically all remain to be scientifically evaluated. There is also no assurance they will yield practical consequences, but they do suggest some obvious new interventions we may wish to consider. Of course in making these suggestions, it should go without saying that how one responds to the emotions of a child must be individualized depending on the child's age as well as the changing dynamics of each living moment. Thus, the following "emotional systems" suggestions are provided more as exercises in possibilities, to encourage further thinking along these lines, rather than as definitive, empirically based recommendations:

SEEKING System

It is beneficial for the organism to have vigorous seeking urges, for this sustains interest in a variety of life activities, incorporating world events into cognitive structures. Developmentally, vigor in this system may be sustained by systematic and graded daily challenges that promote expectancies and the recruitment of self-initiative to fulfill these expectancies. At the same time, the psychic energy of the SEEKING system can probably be expressed indirectly in all other emotional systems, for instance, as in trying to find routes of safety in dangerous situations. All of the bodily needs (e.g., hunger, thirst, warmth) arouse this system, and if needed resources are scarce, we would anticipate that chronic feelings of greediness will emerge as stable psychic structures in young children. Such propositions could be tested by evaluating material possessiveness (hoarding) in adults who had experienced great material need when young.

RAGE

Obviously, the major consequence of anger is aggressive behavior. One of the major ways to arouse anger is to thwart expectancies, and infants are not immune to such influences. Although it is impossible and probably not desirable to eliminate thwarting completely, it is good to remember that the consequences of emotional actions tend to solidify or diminish emotional patterns. Probably the best way to reinforce this emotional pattern is to try to satisfy expectancies during bouts of unjustified rage (i.e., temper tantrums). Perhaps one can diminish this tendency by encouraging infants to work through their rage by *seeking* new and satisfying behavior patterns. In saying this, it is probably best to respond in positive, fulfilling ways to the anger of very young infants (i.e., before they have adequate cognitive appreciation of environmental contingencies), because the mere experience of an emotion, without the capacity for cognitive regulation, may tend to ingrain the aroused emotion as an affective disposition in the brain. Obviously, there is a bit of catch-22 in the organization of these systems, because the more a child seeks, the more likely it is to be thwarted. But age-appropriate challenges are important at every developmental stage, as are age-appropriate explanations for the various forms of thwarting that are bound to occur. A gentle acceptance of infantile tantrums and the utilization of attentional diversion, are probably better strategies than either punishment or acquiescence to childhood ferocities. Those later responses are more likely to cultivate the soil for future characterological problems.

FEAR

Different fears emerge at different ages in children. There is no way to eliminate anxiety, but it is probably best for optimal development if each child grows up in as fear-free an environment as possible. Although the natural aim of fear is to minimize the consequences of danger, if it captures the imagination of a child to too great an extent, it is likely to inhibit the expression of all of the other emotions. It can promote neurotic defenses and unproductive forms of cognitive organization. In this context, it should be obvious that parental punishment can be a double-edged sword. If used, it needs to be swift, mild and followed rapidly by forgiveness when behavioral change is evident. This requires caretakers to effectively regulate their own anger.

PANIC

Separation distress is a natural part of growing up. A clear separation response in infants emerges around eight months of age when fear of strangers first occurs, even though there are antecedents at much earlier ages. It might be good for future development if infants are given graded experiences with separation at an early age (e.g., mother playing with infant in the presence of a friendly stranger, with the mother departing for a brief periods of time). Presumably, if separation distress is mild and reunions are warm and positive, this will solidify pro-social patterns in children (and as we shall see later, animal studies suggest that such maternal attentions may strengthen the nervous system and its responses to stress for a lifetime). Sudden and extreme separations, as may result from parental abandonment, may sow the seed for chronic, life-long tendencies for sadness, depression, and resentment. Of course, all sorrows are generally more difficult to deal with if kept secret, and they are less painful when shared with sympathetic others. At an early age, children should be encouraged to communicate about such matters to caretakers. Children should be given as much active love as they desire. Parents should not use threats of separation to discipline children, for that can only promote neurotic adjustments to the world. Because a great deal of psychosocial development, from basic separation-individuation processes to the establishment of intersubjectivity, is based on the quality of affiliative and attachment issue, I will expand on these issues in a separate section.

PLAY

Young children tend to be very active a good deal of the time. As I will discuss more extensively below, all children need daily doses of rough and tumble (R&T) activities, for this may optimize brain organization. Also, joy tends to counteract negative emotions. There has been a degree of pathologization of this form of early social boisterousness in American society (i.e., it is often mistaken for aggression), perhaps leading to increased diagnoses of ADHD and other impulse control disorders. There are many positive ways to bring this activity back to children's lives, starting with peek-a-boo and tickling games in early infancy. Because boys tend to outweigh and be rougher than girls, special provisions may need to be made for assuring equal R&T play opportunities for all. In general, young children need a great deal of body contact, and they probably enjoy it most in playful forms. Some prefer very R&T activities while others, especially most infants, may prefer to have more Gentle & Tumble play. The use of tickling is probably much underutilized by modern parents as an acceptable and desired form of touch. It is noteworthy that young animals find R&T contact with a human handler to be more rewarding than petting (Panksepp & Burgdorf, 2000). Also, when children play in rough-and-tumble ways under the supervision of sensitive adults who are ready and able to make the various negative emotional experiences, that will invariably arise in the course of R&T play, into positive learning experiences, the future life course of children can only be enhanced. It seems likely that children learn positive social expectations most readily in the living, playful moments of their lives.

LUST

Obviously sexual systems are quite immature in infants, but childhood sexuality is, no doubt, a real phenomenon involving not only oral and ano-genital stages, but whole body somatosensory experiences, any behavior that promotes a child's guilt in relation to such desires and activities is probably counterproductive. Attitudes that accept and even condone the shame-free experience of bodily pleasure, including perhaps some harm-free and guilt-free sexual play between children (clearly a touchy but an important topic), *may* only enhance the long-term happiness and health of each developing child.

CARE

Behavioral neuroscience suggests that nurturance systems have emerged evolutionarily from those that mediate sexuality (e.g., estrogen, oxytocin, prolactin). Young animals and young children exhibit periods of intense nurturance during early development, and in present-day society, every effort should be made to encourage such tendencies in both boys and girls. Indeed, most of the positive aspects of the above emotions can be exercised best in playful circumstances. The cultivation of such affectionate impulses can only pay future dividends. The special roles of mothers and fathers in gender-specific affectional developments deserve continuing attention in both humans and animal models (Fleming et al., 1999; Laviola & Terranova, 1998; Maestripieri, 1999).

It is presumably from these affective systems and their cognitive consequences that most forms of human happiness and unhappiness emerge. PLAY, LUST, and CARE are essential for the emergence of lasting social satisfactions, and SEEKING is essential for probably all other forms, including the opportunity for organisms to experience the transient pleasures of the various sensations related to homeostatic needs. The above is not meant to argue that there are no other basic emotional systems, but simply to highlight those whose existence we can agree on with some confidence. Perhaps the most important emotional dimension that is not included above is that of "dominance," which we presently conceptualize as emerging from the interactions of many processes mentioned above; and dominance issues emerge, no doubt, even in the minds of infants as essential elements of SELF-expressions, providing major guiding forces in ego-development (Hawley, 1999). Also, the above analysis has neglected to focus on the importance of right versus left hemisphere functions in the mediation of emotionality, but those issues have recently been extensively discussed elsewhere (Davidson & Hugspeth, 1995; Ornstein, 1997; Schiffer, 1998).

As we come to terms with the types of ancient emotional systems that exist in human brains (e.g., Damasio, 1999; Panksepp, 1998a), we are beginning to recognize that affective feelings emerge from the convergence of emotional circuits on subtle SELF-representation systems of the brain (the "core self" in Damasio's terms). These systems, that reflect neuro-symbolic instantiations of critical bodily states, allow us to have those feelings that create a sense of identity within the individual—a sense of ownership for our perceptions, our thoughts, and our knowledge structures. The infant is born with reasonable competence with many basic emotional and bodily feelings, but obviously, a very limited capacity to understand the meaning of their feelings. Those emerging knowledge structures, for good or ill, are strongly guided by how their social worlds interact with their emotional strengths and weaknesses—a general view originally espoused by Freud (see Solms & Nersessian, 1999).

Because infants must communicate nonverbally with various gestures, body attitudes and primitive vocalizations, caretakers need to be highly attuned to such communications (Beebe et al., 2000; Malloch, 1999/2000). The more a child's emotional needs can be anticipated and properly reciprocated, the richer will be the positive informational matrix and the positive sense of intersubjectivity that solidifies in the child's cognitive apparatus. If an infant has to cry in distress for all its needs, its informational structures will remain more impoverished, and gradually, chronic resentments may well emerge for both the infants and caretakers (Drummond, Letourneau, Neufeld, Harvey, Elliott, & Reilly, 1999). Thereby, their whole life course may be affected. Conversely, it should be remembered that the infant's cognitive-affective-perceptual apparatus is probably also highly attuned to nonverbal gestures, facial expressions and tones of voice, allowing early intersubjective resonances that are surely important for sculpting each child's internal affective landscape (Beebe et al., 2000; Blum, 1993). Caretakers need to be cognizant of such issues, and if their own temperaments do not resonate with such information channels, societal opportunities need to be constructed for the acquisition of the needed skills.

The basic emotional systems appear to have both core neural and psychological attributes. At the neural level each system has peptidergic codes, and all are also controlled by all of the biogenic amine, cholinergic, and amino acid systems (Panksepp, 1993a, 1998a; Schore, 1994). In essence the "affective neuroscience" view advocated above, recognizes (1) that emotional "command systems" generate an intrinsic action-readiness that characterizes both human and animal emotions, (2) that there are various homeostatic interoceptive detector systems that reflect fundamental regulatory urges of organisms and that modulate many emotions, especially SEEKING urges, and (3) that there are ways to broadcast these influences widely in the brain through mechanisms such as the extended reticulothalamic activating systems of the brain. According to the present view, the feeling of an emotion is generated in the brain by the various basic emotional systems influencing a primordial neural representation of the body in the upper and middle brainstem, a process that I have labeled the SELF structure, and Damasio (1999) has called the "core self." Because this is the most controversial aspect of the present view and has recently been covered in detail elsewhere (Damasio, 1999; Panksepp, 1998a, 1998c), I will not discuss it further here. Let me simply assert that it is probably through the epigenetic influences of these core SELF structures that the deep affective qualities of children become solidified into habitual ways of being. The emerging cognitive structures then begin to regulate how each individual deals with feelings, whether it be openly or in more repressed and other pathogenic ways.

Every emotion, if it remains unexpressed, has the potential to go underground and persist as an unresolved tension that can become an undesired force within the nervous system—persistent feeling tendency in subjective experience. Although repression can reduce the felt intensity of emotions, in general, it would seem that a rich emotional intelligence will emerge more readily if infants and children are allowed to express their feelings fairly freely, and if feelings are explicitly recognized and respected in the mental economy of their lives. If certain emotions are excessively obstructed or punished, they may emerge later as pathological desires and impulses that can have psychiatric consequences. If children are allowed relatively free affective expressions in the context of emotionally intelligent adult guidance, then they are more likely to develop healthy psychic habits and productive emotional self-regulation skills.

Obviously, all of the basic emotional systems help establish long-term character and cognitive structures that ultimately reflect the many strengths and weaknesses of individual lives. Unfortunately, only preliminary knowledge is available at the neuroscience level on how the underlying emotional circuits interact with cognitive structures (e.g., Borod, 2000; LeDoux, 1996; Toga & Mazziotta, 2000). However, what should be of great scientific concern from the present perspective, are the ways that affective experiences may mold and modify the sensitivities of the basic emotional substrates quite directly (Adamec, 1997).

PLASTICITY OF EMOTIONAL SYSTEMS LEADING TO SUSTAINED PERSONALITY EFFECTS

Progress in affective neuroscience, much of it emerging from animal models, may eventually convince some caregivers to adjust their rearing practices to optimize development, but there is little good data to guides such choices. In fact, the amount of work on plasticity of brain emotional systems is miniscule, so I will only briefly dwell on some key issues that need to be empirically resolved. All of the emotional systems discussed above have essential neural underpinnings (Panksepp, 1998a), and it will be most interesting to determine, in animal models, the extent to which early experiences can modify the strengths of the underlying neural substrates.

Can we make organisms chronically angrier by excessive early thwarting? Can we make organisms more fearful by an abundance of early threats? Can we make them more curious, more loving, more sad with those respective experiences? Can we reduce the incidence of sexual problems by certain early experiences? Probably we can, but the existing data base is modest, and for each suggestive finding, it is still necessary to work out the underlying neurobiological details. So far, the most compelling findings come from animal kindling studies, where the permeability of affective systems to incoming stimuli can be increased by electrically stimulating specific emotional circuits (Adamec, 1997).

Let me suggest some specific experimental strategies that should be pursued: because we have considerable knowledge about the essential neural components for some of the basic emotions (Panksepp, 1998a), we need to determine how various life experiences in animals modify the number of neurons and dendritic and axonal arborizations of each system. We need to determine how the key neurochemistries in these systems and their genes, both pre- and postsynaptic are regulated. For instance, it is known that sexual hormones can modulate vasopressin levels in males and oxytocin levels in females, and we know that short-term sociosexual experiences can dramatically effect these systems (Carter, Kirkpatrick, & Lederhendler; 1997). Unfortunately, aside from some dynamic morphological features in adults (Pederson, Caldwell, Jirikowski, & Insel, 1992), we know essentially nothing about how these systems are molded in the long-run by experiences during early development. However, there are excellent neuroscience tools available to address such questions, and they must now be deployed vigorously for us to understand how adult emotions are molded by infantile experiences.

Finally, we need to determine the extent to which we can alleviate the impact of the negative emotions and facilitate the impact of positive emotions in children's lives through early interventions, thus defining optimal kinds of upbringing. We probably all suspect that lives could be positively molded in these ways, but again, the most rigorous scientific approach is to evaluate such issues in animal models, where we can clarify the underlying details. Will such findings impact on long-term human mental health issues? We probably all believe that they can, for there is considerable evidence for the powerful developmental influences such as the experiences of social loss (Atkinson & Zucker, 1997), but we only have the vaguest hints of the underlying causes (Kraemer & Clarke, 1997). Still, we can be confident that early attachment experiences do guide the emergence of future social skills and one's subjective sense of life-quality (Bretherton, 1997; De Wolff & Van Ijzendoorn, 1997). Presumably infants' fundamental wishes and fears are related to the qualities of attachment they experience at the primary process level, and those primary-processes appear to be quite similar in all mammals.

THE CASE OF SEPARATION DISTRESS AND BONDING

It was our work on separation distress, starting with the endogenous opioid theory of bonding, that first addressed the very nature of the brain processes that mediate attachment within the mammalian brain (Panksepp, Herman, Villberg, Bishop, & DeEskinazi, 1980; Panksepp, 1981). This work has been impressively advanced and diversified by others (Insel, 1997; Kehoe, 1989; Kalin, Shelton, & Lyn, 1995; Keverne, Nevison, & Martel, 1999).

In short, our working assumption for the past quarter of a century has been that a study of the neural infrastructure of the mammalian separation-distress and play systems provide the best foundation for understanding the biological nature of the secure base that each infant needs to thrive and progress effectively toward psychological maturation (Panksepp et al., 1988). Although for a long time behavioral neuroscience investigators did not acknowledge the existence of unique neural systems for social emotions (believing attachments emerged secondarily from primary reinforcers such as maternal provisioning of food, water, and warmth), the existence of an integrative emotional system for social affect is now definitive. However, the detailed nature of the system, its interaction with other brains systems, and its various developmental consequences deserve a great deal more work (Panksepp, Knutson, & Pruitt, 1998). For instance, despite the increasing recognition of attachment disorders in humans (O'Connor et al., 2000; Schmidt & Schulkin, 1999), the nature of the human attachment system remains uncertain. Despite extensive discussions of the issues (Klaus & Kennell, 1982) it is *not* yet possible to conclude, at least on the basis of hard empirical evidence (Lamb & Hwang, 1982; Morgan, 1981; Myers, 1984), that human mothers do, in fact, have a restricted sensitive period for bonding with their infants soon after birth in the way certain other mammals do (Rosenblatt & Snowdon, 1996).

Indeed, because human infants are born so immature, we can anticipate that the sensitive phase for bonding is very prolonged. In altricial species like ourselves, there is no ecological need for rapid bonding, as there is in precocious species such as ungulates who are born "ready to run" (Lamb & Hwang, 1982; Levy, Kendrick, Keverne, Porter, & Romeyer, 1996). Despite such differences in details, we have every reason to believe there is a shared neurobiology of attachment processes in all mammals (see Carter et al., 1997; Nelson & Panksepp, 1998), even if the "bonding window" varies markedly from one species to another. In our species, loving feelings between mother and child do emerge quite early, and in most cases intensify as development proceeds. Thus, in human mothers, the postulated "sensitive period" of bonding may simply consist of little more than gradually changing sensitivity of emotional responses toward infants, which are commonly reflected in their desire to interact with and provide care.

That these early attachments would become strongly associated with a specific child (apparent imprinting), yielding social discriminations of various kinds (i.e., preferences and investments in one's own children) should also be expected. However, because of the massive and unresolved controversies that have surrounded the concept of "bonding" (e.g., see Eyer, 1992), in the present context it is used simply as a synonym for "attachment" processes, with no assumption that this can proceed only in a narrow time-frame following birth.

The underlying neurobiological processes that mediate bonding surely fluctuate greatly as a function of development, with considerable species-typical, gender-typical as well as individual variation in the underlying processes. Thus, we should still remain open to the possibility that there are remarkably sensitive phases for mother–infant bonding in humans, but proper evaluation of such possibilities would require sensitive affective measures of infant acceptance and interest, emotional responses to infant loss, and the putative underlying neurohumoral controls (e.g., oxytocin, prolactin and steroids). Simply focussing on cognitive opinions that may be strongly influenced by cultural display rules may not suffice. The modest amount of relevant data that is available does suggest that something very special is happening neurobiologically soon after birth even in humans (Fleming, Ruble, Krieger, & Wong, 1997a; Fleming, Steiner, & Corter, 1997b). Most tend to call this love, and we should certainly consider that this type of mind-brain process arises largely from the underlying neurobiology of basic mammalian attachment processes (Carter, 1998; Nelson & Panksepp, 1998).

Obviously, the expressions of human attachments are a life-long phenomenon, but this sustained process has proven to be difficult to study, in humans as well as other species. It has probably been studied most extensively under the concept of maternal "sensitization"—the experience-induced maternal urges that can be evoked by prolonged exposure of animals to young infants (Krasnegor & Bridges, 1990; Stern, 1996). The mere experience of motherhood tends to produce a life-long increase in maternal urges. In other words, mother animals sensitize more rapidly than females that have never had babies. It also remains possible that the underlying neurobiological mechanisms for this type of social acceptance and bonding are quite similar to those that sustain the affective side of friendships. This would again affirm that bonding is based on a highly generalized and potentially life-long process in humans, which may decline only gradually as a function of age.

In any event, many investigators share the assumption that with a secure and loving psychological base, infants can weather many other emotional storms. The travails of life that activate the separation system are related to the perception of social presence and absence, which can be detected, to some extent, by all of the exteroceptive sensory modalities—even though sight, sound, and touch are of foremost importance in humans. In certain animals, we know that the activation of the separation response is organized around various neurochemistries [e.g., glutamate, corticotropin releasing factor (CRF)], as is the comfort of social presence (e.g., via endogenous opioids, oxytocin, and prolactin) (Nelson & Panksepp, 1998; Panksepp, 1998a) along with a variety of other chemical contributors that may be more important for adult attachments (e.g., vasopressin and dopamine) (Insel & Winslow, 1998). Presumably, the perceived presence or absence of social support is mediated by the distressing and soothing effects of such chemistries, and the dynamics of the underlying brain systems create the affective texture of the secure base. In young animals some of the most beneficial changes may result simply from loving touch, some of which may emerge from oxytocin and endogenous opioid release, which are known to solidify infant–mother bonds (Nelson & Panksepp, 1996; Panksepp, Nelson, & Siviy, 1994).

The positive effects of touch for infant development were first highlighted in the studies of Spitz (1965). Since then, it has become evident that extra touch can promote development in premature infants (Barnard & Brazelton, 1990; Field, 1993), and that various beneficial effects of touch can be seen in animal models, including induction of growth promoting factors (Schanberg & Kuhn, 1985) and activation of many brain systems, especially oxytocin release (Uvnas-Moberg, 1998).

One of the best detailed touch-related developmental vectors that has been worked out is the beneficial effect of early "handling" on the stress-responsivity of young animals (Meaney et al., 1991). I place *handling* in quotation marks because early in the analysis of this phenomenon it was found that simply isolating young rats for 3–15 minutes each day could also produce the "handling effect," suggesting that experimenter handling was not the critical feature. In any event, the beneficial long-term consequences of this simple manipulation were profound, including protection against age-related decline in the hippocampal functions (Meaney, Aitken, van Berkel, Bhatnagar, & Sapolsky, 1988). However, then it was suggested that these benefits may actually be arising neither from separation nor from handling per se, but from the increased maternal attention, including the abundant licking and grooming that isolated pups receive from the mother upon reunion.

Quite similar beneficial long-term effects in the hippocampus were reported in pups that received the most abundant maternal attention, as indexed by amount of licking and hovering (Liu et al., 1997). Indeed, the apparent beneficial changes in such animals were not restricted simply to cognitive functions but also to emotional ones, because the animals that were licked the most also exhibited the least fear in adulthood (Caldji, Tannebaum, Sharma, Francis, Plotsky, & Meaney, 1998). A shortcoming of these initial studies was that some of the above effects may have been due to uncontrolled maternal genetic factors rather than simply the maternal behaviors exhibited—factors whose influence could not be partitioned because of the lack of any crossfostering controls. However, these methodological problems have recently been rectified (Francis et al., 1999), and the effects are, in fact, due to the maternal behaviors. Accordingly, these findings fit remarkably well with the compelling idea that parental behavior *can* have decisive biological consequences on the future development of their offspring, and that neonatal stress responsivity in humans can predict their subsequent temperamental profiles (Gunnar, 1998; Schmidt et al., 1997).

One of the villainous "stars" of all of the above separation studies appears to be brain CRF, which integrates many of the negative affective consequences arising in the nervous system as a function of maternal separation. Persistent changes as a result of early separation experiences have repeatedly been demonstrated in this system (Cratty, Ward, Johnson, Azzaro, & Birkle, 1995; Smith, Kim, van Oers, & Levine, 1997; van Oers, de Kloet, & Levine, 1998; Workel, Oitzl, Ledeboer, & de Kloet, 1997), and this system also figures prominently in the genesis of depression. These changes can result from excessive stimulation of aminergic and other autonomic neurons in the brain stem (Caldji et al., 1998; Heim, Owens, Plotsky, & Nemeroff, 1997; Ladd, Owens, & Nemeroff, 1996). Indeed, as already noted, CRF circuitry appears to be the very heart of the separation-distress system of the mammalian brain (Panksepp, Crepeau, & Clynes, 1987; Panksepp et al., 1988).

It is now well recognized that severe early separation experiences have life-long consequences for the emotional health of children. Excessive separation experiences set up the young child for future depression (Kendler et al., 1993) and panic attacks (Silove et al., 1996), feelings of sadness, and devastation. It is reasonable to suppose that milder effects on this brain system could establish chronic shyness and introverted tendencies in children (Kagan, Reznick, & Snidman, 1987; Gunnar, Brodersen, Nachmias, Buss, & Rigatuso, 1996; Schmidt & Schulkin, 1999) and perhaps life-long tendencies toward submissive behaviors and feelings of defeat in adulthood. The chain of events between these developmental stages remains unspecified, but it will presumably have a great deal to do with changes in the vigor and sensitivities of the underlying neuroemotional substrates (Panksepp, Knutson, & Pruitt, 1998; Panksepp & Miller, 1996). Because of current ethical standards, such issues are hard to evaluate in humans or other primates, which leaves considerable room for development of more efficient experimental models in simpler animals (Panksepp, Yates, Ikemoto, & Nelson, 1991), with an aim toward measuring the activity of brain emotional systems objectively (Panksepp, 2000a).

Although it is easy to imagine the types of new medications that could be developed to alleviate feelings of separation distress (e.g., CRF antagonists, *mu* opioid, and oxytocin agonists), it is not at all clear whether they would have beneficial effects on long-term psychological development. Chronic use of CRF antagonists could leave infants susceptible to other problems such as colitis (Million, Tache, & Anton, 1999). Early exposure to opiates can have prolonged and wide-ranging developmental consequences (Zagon, Zagon, & McLaughlin, 1989); on the other hand, in our experience, treatment of infant rats with high intracerebral doses of oxytocin during development has had no noteworthy consequences for their physical or psychological development (Burgdorf et al., 1998). One can also imagine that pharmacological modulation of these chemistries might alleviate early bonding problems between mothers and children (Panksepp et al., 1994a), but at present there is insufficient evidence to make any data-based prescriptions in this realm. However, relevant primate work on such issues remains promising (Kalin et al. 1995; Keverne et al., 1999).

PATHOLOGIES OF "BONDING"—THE CASE OF AUTISM

Although the quality of bonding is bound to have broad scale ramifications on the development of normal children, there are also specific psychiatric issues to be considered. At least part of early childhood autism may be due to brain abnormalities in systems that mediate emotions related to social attachments (Panksepp & Sahley, 1987). One early brain hypothesis was that excess influences of endogenous opioids may cause social aloofness (Panksepp, 1979), and this view has gained some support from the modest benefits that can be obtained from opiate antagonists such as naltrexone in a subset of autistic children (e.g., Kolmen, Feldman, Handen, & Janosky, 1997; Panksepp, Lensing, Leboyer, & Bouvard, 1991). Additional support for an opioid vector in autism comes from recent evidence that dietary absorption of poorly digested milk or wheat proteins may lead to high circulating titers of exorphins such as the casomorphins (Shattock & Lowdon, 1991), molecules that can modulate brain social processes (Panksepp, Normansell, Siviy, Rossi, & Zolovick, 1984; Sun, Cade, Fregley, & Privette, 1999).

As predicted from the opioid theory of social attachments, animal studies do indicate that high levels of opioids make animals less gregarious (Panksepp, 1981), while opioid blockade can make many kinds of animals, including primates, more eager to socialize (Kalin et al., 1995; Keverne et al., 1999; Panksepp, Conner, Forster, Bishop, & Scott, 1983). Likewise, young rats exhibit an especially intense desire to interact with baby rats during their early juvenile period (Krasnegor & Bridges, 1990), and the decline of this type of motivation during the mid-juvenile period correlates with the maturation of β-endorphin systems in the brain (Mann, Goltz, Rigero, & Bridges, 1999). All this suggests that developmental changes in endogenous opioids may regulate feelings of social interest and independence. Because social aloofness is a common characteristic of autism, sustained overactivity of such brain systems could chronically change social motivation.

Of course, most researchers now recognize that autistic symptoms may be the endpoint of genetic disorders as well as a large number of other central nervous system insults. Indeed, the increasing incidence of autism during the last few decades may implicate environmental vectors (Rimland, 1999). Among those being most actively considered besides dietary factors (Shattock & Lowdon, 1991; Whiteley, 1999), are rare autoimmune disorders that may arise from viruses (Singh, Warren, Averett, & Ghaziuddin, 1997; Singh, Lin, & Yang, 1998) or perhaps even a hyperresponsiveness to early inoculations with certain vaccines (Wakefield et al., 1998), although no convincing epidemiological data on that issue has ever been published. Of course, with the overall low incidence of such iatrogenic problems, it will be difficult to verify the role of specific vectors in rigorous ways (Fombonne, 1999). Parenthetically, certain immunotherapeutic interventions do show some promise in the treatment of pervasive developmental disorders (Singh, 1997).

Probably all environmental vectors that may contribute to pervasive developmental disorders will remain quite difficult to investigate (Koliatsos & Ratan, 1999), because such variables probably interact with unknown constitutional susceptibility factors. For instance, one could make a cogent argument that neurotoxic dietary vectors such as glutamate may contribute to the disorder, especially because there appears to be a degree of abnormal hypersensitivity to such agents in the general population (Baylock, 1994). The reason such sensitivities exist is unknown, but it is noteworthy that, as a population, autistic children exhibit many problems of the gastrointestinal lining that may lead to abnormal absorption of metabolites and neurotoxins (i.e., via a “leaky gut”) that might not otherwise have access to the nervous system. It is also possible that there are elevated levels of various environmental neurotoxins that may have special impact on a number of susceptible individuals.

To evaluate the possibility that one such a vector, an abnormal glutamate cascade in the brain, might contribute to autistic disorders in sensitive individuals, we monitored the behavioral changes in young animals that had been exposed to peripheral injections of the glutamate-like neurotoxin kainic acid (Olney & Farber, 1995). Indeed, animals with this type of brain injury, which includes diffuse damage to various limbic areas and reticular nuclei of the thalamus, yields a striking autistic-like syndrome (Gordon, Panksepp, Secor, Burgdorf, Turner, & Bingman, 1998): Such animals are generally hypertemperamental, socially strange (incapable of sustaining normal social interchange, as in social play), and they exhibit a remarkable degree of tactile defensiveness (i.e., they cannot be picked up without squealing). These consistent temperamental changes are leading us to consider a role for glutamate-type neurotoxicities (whether endogenous or exogenously induced) in the emergence of autistic symptoms. Although this is bound remain just another controversial hypothesis for the foreseeable future, one of the beneficial functions of animal models is to allow us to think in neurological realms that would otherwise be closed to our imaginations. The next topic is also a striking example of that same principle.

THE CASE OF PLAY, JOY, AND LAUGHTER

Do children who experience a great deal of joy during their early years solidify a positive long-term outlook on life? Although most might agree with such a supposition, there is little relevant data available. It would not be an understatement to say that we know less about the neurobiological sources of joy than any other basic emotion of the mammalian brain. Our own research strategy for the past few decades has been to see whether this problem could be addressed by trying to unravel the neural sources of play and perhaps even laughter in animals. Yes, because of accruing data, we have become open to the possibility that some other animals not only play, but that they also may laugh (Panksepp, 2000c).

There is something primitive about human laughter and childhood play. The stereotyped vocal pattern of laughter first appears in rudimentary form at two to three months of age (Rothbart, 1973; Stroufe & Waters, 1976), and the desire for playful interaction gradually intensifies thereafter. With each stage of motor and psychological maturation, playfulness gets more complex, going from tickle games, to rough-and-tumble play to fantasy games. In these endeavors, emotional systems captivate cognitive processes, increasing the subtlety of intersubjective states from the earliest ages onward (Fivaz-Depeursinge & Corboz-Warnery, 1999). Indeed, the nuances of adult humor highlight how ancient emotional processes interact with our cognitive abilities within higher reaches of the brain-mind (Freud, 1905/1960).

Play has long been recognized in all other mammalian species. Its evolutionary relative, laughter, is now recognized in other primates (Provine, 2000) and a robust database allows us to consider the existence of this primitive neural process even in simple-minded mammals such as rats (Panksepp & Burgdorf, 1999, 2000). Of course, because laughter is best understood in our own species, the human phenomenon must remain the criterion against which investigations of the “laughter” of other animals must be judged. However, the apparent existence of laughter-like vocal activities in a diversity of species does suggest that a fundamental brain processes for joyful social affect may have emerged early in vertebrate brain evolution.

Here I shall briefly summarize what little we know about the evolutionary and brain sources of laughter and play, and how the accompanying positive emotions may solidify social bonds and friendships within the mammalian brain. Of course, laughter is fundamentally a social phenomenon, and in young children it is most easily evoked by playful tickling. The perennial childhood puzzle—"Why can't I tickle myself?"—may simply be answered by the fact that the critical brain systems are controlled by the unpredictability of social interactions—of being rapidly approached and chased by friendly individuals. Presumably such playful interactions help weave individuals into the surrounding social fabric and to establish and affirm the dominant qualities of social relations.

Indeed, if one wants to rapidly become friends with a young child, there is no better way to negotiate the social terrain than gently escalating tickle games (an enticing idea that remains to be experimentally verified, although it can empirically observed by any sensitive adult who wishes to do so . . . I have done it personally many times). The fact that certain parts of the body are more ticklish than others, both in humans and animals (Harris, 1999; Panksepp, 1998a) and the fact that a unique type of vigorous play-touch is essential to evoke tickling, highlight the potential existence of specialized receptor organs in the skin and pathways in the brain that may specifically mediate this response. But again, there is no substantive work on such important issues.

Infants' delight in tickling paves the way for peek-a-boo games (Parrott & Gleitman, 1989). The anticipation of sudden social presence and absence can magnetize the delighted attentions of infants. These antecedents may pave the way for their eventual enjoyment of unpredictability in games, as well as in mischievous pranks and practical jokes. Throughout childhood, laughter occurs most commonly and most intensely in the midst of vigorous social engagements, such as the chasing and running activities of rough-and-tumble play. The same appears to be the case in young rats. When young rats are tickled, they exhibit a high-frequency chirping response that has many of the characteristics of human laughter (Panksepp & Burgdorf, 1999, 2000).

Because smiling and laughter are the quintessential indices of joyful feelings in all human cultures (Scherer, Wallbott, & Summerfield, 1986), a close analysis of the underlying brain systems may help us reveal the basic nature of social joy within the brain. Clearly, different individuals and organisms differ greatly in their capacity for fun and laugher, but we presently know next to nothing about the underlying psychobiological causes. When we eventually do, we may be able to empirically ask whether early infantile experiences help solidify a better sense of humor within the brain. If the primitive neural substrates for social joy are, in fact, similar in rats and humans, animal experimentation will allow us to fathom such issues more readily than any studies that could be conducted in humans (Panksepp & Burgdorf, 2000).

Parenthetically, most of what we presently know about the neuroanatomy of laughter has been derived from clinical analysis of certain brain disorders. It has long been known that the progressive diseases in which the insulation around nerve cells (i.e., myelin) begins to degenerate, such as multiple sclerosis and amyletrophic lateral sclerosis, are commonly accompanied by fits of crying and laughter (Black, 1982; Feinstein, Feinstein, Gray, & O'Connor, 1997). Often the crying bouts set in first, followed by laughter, but typically, neither is accompanied by the appropriate affect (Poeck, 1969). They are typically motor displays which reflect release from inhibition of deep subcortical motor circuits situated in the brain stem. Although neurobiological work on laughter, joy, and a sense of humor remains in its preliminary stages (Fried, Wilson, MacDonald, & Behnke, 1998; Panksepp & Burgdorf, 2000), we can anticipate that future work along such lines will have important implications for mental and perhaps bodily health issues, both at diagnostic and therapeutic levels (Parse, 1994; Sakamoto, Nameta, Kawasaki, Yamashita, & Shimizu, 1997).

It will be most interesting to establish the relationships between the tendency to laugh and play and mental health outcomes, especially in children. Can the tendency for mirth and laughter be established as an emotional trait variable early in life, and will this trait have some predictive validity in reflecting the developmental progression of a child? Now that we are beginning to understand play circuits of animals (Panksepp, 1993b, 1998b, 2000b; Vanderschuren, Niesink, & Van Ree, 1997) and to recognize that other animals also exhibit laughter-type responses (Panksepp, 2000c), the utilization of animal models to address such basic questions may be especially informative. The type of somatosensory stimulation experienced during play and tickling may have positive neural consequences similar to those reported in maternal handling experiments (Caldji et al., 1998; Liu et al., 1997), but such issues remain to be evaluated.

"PATHOLOGIES" OF PLAY

Although relevant data are scarce, young organisms probably learn many emotional lessons through play, but the long-term psychological consequences have only recently been empirically addressed (Terranova, Cirulli, & Laviola, 1999; van den Berg, Hol, Van Ree, Spruijt, Everts, & Koolhaus, 1999). Surely, this type of psychomotor activity is important for normal brain and psychological maturation. The eagerness of young animals to indulge in such behaviors indicates that a deep psychobiological need for this type of activity exists within the brain. This is most dramatically indicated by the fact that animals deprived of play have a much stronger urge to indulge in the activity than animals that have received abundant opportunities to play. Play is tightly regulated both in short- and long-term developmental time frames (Panksepp, Sivy, & Normansell, 1984), but the specific aspects of brain functions (e.g., neurochemical balances, synaptic connectivities?) being regulated remain unknown.

Despite our ignorance about the underlying neural issues, I and others have raised the possibility that much of what is presently diagnosed as ADHD in our children may largely reflect the *natural* tendency to express ludic and other childhood urges in inappropriate social situations (Jensen et al., 1997; Panksepp, 1998b). Animal research has clearly indicated that psychostimulants typically used to treat ADHD are remarkably powerful play inhibitors (Vanderschuren et al., 1997), and presumably these agents are found to be so beneficial in school settings not simply because they can facilitate externally directed attention but also because they reduce impulsive playful urges. Accordingly, one useful psychosocial intervention that may reduce impulsivity in children is to increase daily doses of R&T play at appropriate times of day (Panksepp, 1998b). In this same vein, we must consider how very early playful experiences in infants may impact on play tendencies at later stages of development. Might it be that too much early R&T play will only strengthen such urges, causing even more problems in the classroom? Although no human data are available on such issues, the animal data indicate just the reverse—animals that have not had much play tend to remain more eager for play when they are older (Panksepp et al., 1984b).

The above is an especially urgent issue because across the past decade there has been a increasing tendency to utilize psychostimulants in younger and younger children and because it is possible that the utilization of such agents may tend to sensitize the nervous system of young organisms as it does in adults (Pierce & Kalivas, 1997). Although sensitization has not been empirically demonstrated in human children (nor has it been properly evaluated), in adult animals such drug experiences do lead to personality changes, characterized by increased seeking urges, and heightened tendencies to become "hooked" on various drugs of abuse (Nocjar, 1996; Robinson & Berridge, 1993).

It is generally recognized that ADHD symptoms arise in part from the slow maturation of the frontal lobes in early development—an area of the brain that is essential for higher order types of emotional self-regulation (Barkley, 1997). There are theoretical reasons for suspecting that playful activities during development might promote frontal lobe maturation. Indeed, an ADHD type of syndrome can be produced by unilateral damage to frontal lobe tissue in young rats, and to some extent the resulting impulsivity can be reduced by providing animals with abundant opportunities for R&T play (Panksepp, Burgdorf, Turner, & Walter, 1997). Will children deprived of normal amounts of play during development exhibit slower neuronal maturation of such brain areas? Might long-term psychostimulants modify neurodevelopmental processes in beneficial or undesirable ways?

The ability of psychostimulants to lead to synaptic reconfiguration in animals has been recently demonstrated (Robinson & Kolb, 1999), and we must remain alert to similar types of effects occurring in our children. Indeed, one must question the wisdom of utilizing any brain manipulations on young children that are outside the range of normal psychosocial practices, unless there are clear and unambiguous medical problems and developmentally well-evaluated interventions. On both counts, one can suspect that utilization of psychostimulants is a highly debatable practice (Angold, Erkanli, Egger, & Costello, 2000). More and more concerned professionals are beginning to wonder if ADHD is really much more than an incompatability between normal variants of childhood temperaments and the environments in which they are being educated (e.g., Jensen et al., 1997).

A SYNOPSIS OF DEVELOPMENTAL GOALS

Although emotionality may be deemed, by some, to be a minor issue on the broad canvas of development, it is a power that can be decisive not only in the quality of individual lives but the overall intellectual development of children. Ultimately, the genetically and environmentally induced strengths and vulnerabilities of emotional systems get played out in the higher cognitive spaces of the brain. The executive functions of the frontal lobes are especially decisive in the solidification of character structures, and hence, determining the way individuals lead their lives in the environments in which they find themselves. Let me try to encapsulate the hopes for our children in one diagram that attempts to summarize what many believe are the cardinal functions of the frontal lobes in development (Figure 1).

As summarized by Barkley (1997) in his synthesis of *ADHD and the nature of self-control*, the maturation of the frontal lobes promotes and channels the ability of children to reflect upon their circumstances, to imagine future possibilities, to share emotions with others, and to confront the world with a creative and playful attitudes. The frontal lobes integrate basic emotional processes with cognitive deliberations, gradually yielding the emergence of a natural self-restraint. Ultimately, the frontal lobes allow us to project our feelings and aspirations forward and backward in time, so as to increase behavioral flexibility and foresight in the service of well-focussed goals and hopefully the emergence of socially responsible behaviors. The frontal lobes allow us to appreciate that our lives need not simply be chained to our appetites, and they also allow us to read the contents of other minds. If R&T play helps promote the maturation of such brain systems, it could be used to enhance our educational efforts by maximizing such neuronal developments in our children. Rich emotional encounters with the world from the earliest days of life remain among the best general recipes for achieving those ends. Thus, one

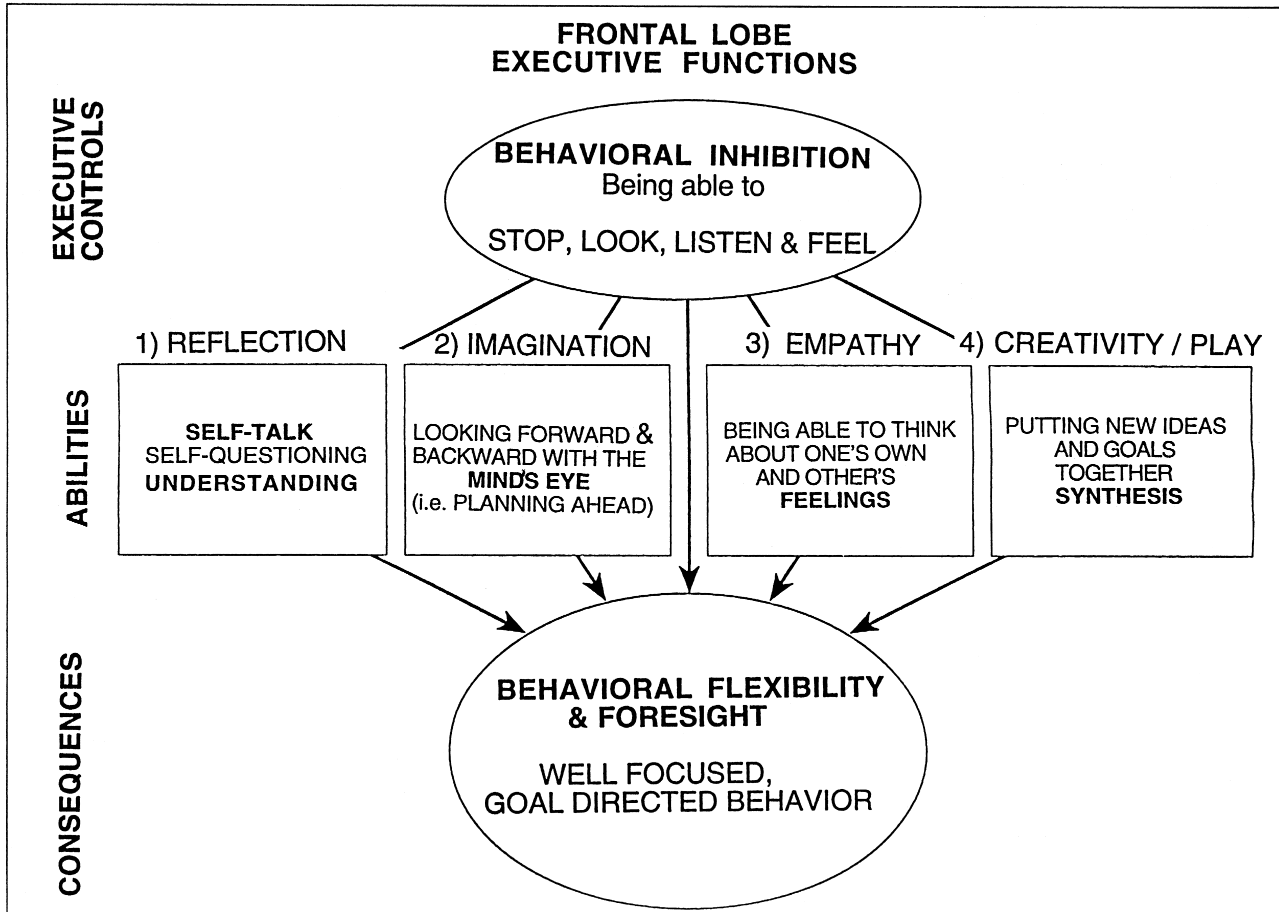

FIGURE 1. A synoptic overview of frontal lobe functions that may be slow to mature in children diagnosed with attention deficit hyperactivity disorders (adapated from Barkley, 1997, and reprinted from Panksepp, 1998b, with permission from the American Psychological Society and Blackwell Publishers).

critical future developmental research projects in animals must be the full evaluation of how early R&T play affects brain maturation. It may have profound implications for the character formation of our children.

THE FUTURE: EXERCISING THE BRAIN WITH BOTH OLD AND NEW MANEUVERS

In addition to optimizing socio-emotional environments, it is easy to envision that exposure to a variety of other experiences might strengthen emotional and brain executive systems. Indeed, it is conceivable that certain moderate challenges may have substantial positive effects while more intense challenges would compromise optimal development. Abundant work has been devoted to analyzing the pituitary–adrenal responsivity in animal models, and robust long-lasting changes are evident as a function of early experiences (Cratty et al., 1995; Heim et al., 1997; Ladd et al., 1996; Smith et al., 1997; van Oers et al., 1998; Workel et al., 1997).

Although modest stressors do strengthen these systems, strong stress is bound to be detrimental. Indeed, findings similar to the above animal findings are evident in human studies (Pike et al., 1997; Wadhwa, Dunkel-Schetter, Chicz-DeMet, Porto, & Sandman, 1996), and include studies of abused children with major depressive disorders who exhibit chronic hyperresponsivity of the pituitary–adrenal stress system (Kaufman et al., 1997). Considering how powerful positive social contact is in reversing the consequences of stress in animals (Maccari, Piazza, Kabbaj, Barbazanges, Simon, & LeMoal, 1995; Ruis et al, 1999; Terranova et al., 1999), one could anticipate that positive social interventions soon after traumatic events could do much to block the long-term negative consequences of those events.

Indeed, we might even anticipate that the use of other stimuli that mimic social-affective processes, such as soothing music, may have positive effects on development. There are some data, and abundant speculations, concerning the potential positive effects of exposing fetuses and newborns to such stimuli (Blum, 1993). We can even envision that direct exercise of certain brain systems might promote positive forms of neural plasticity, as might be achieved through mild brain stimulation with rTMS (transcranial magnetic stimulation) (Muller, Toschi, Kresse, Post, & Keck, 2000) an intervention that is presently receiving substantial attention as a potential treatment for drug-resistant depressive disorders (Pasqual-Leone, Tarazona, Keenan, Tormos, Hamilton, & Catala, 1998). How one might ethically evaluate such issues is outside the scope of the present article, but they are mentioned merely to highlight the increasing number of unusual possibilities that are emerging, and will continue to emerge, not only from the frontiers of brain research but also speculative thinking within the biomedical community.

I urge readers not to dismiss any options, but to certainly insist that all be fully evaluated in animal models for safety as well as indications of efficacy. For example, during the last few years the utilization of Auditory Integration Training (AIT) swept through America as a potential treatment for autism and other neurodevelopment disorders (Rimland & Edelson, 1995). Accordingly, we proceeded to evaluate the effects of this treatment on an animal model—newborn domestic chicks. To our surprise and delight, the manipulation had robust effects on increasing levels and turnover of norepinephrine in the brain (Bernatzky, Panksepp, Rossi, & Narayanan, 1997; Bernatzky, Panksepp, Burgdorf, Nordholm, & Jung, 1998), a system that has long been implicated in the regulation of attentional processes. Now, at least we can be confident that the manipulation may have some robust brain effects that outlast the auditory experience. However, the accurate evaluation of what neurobioloigcal effects such treatments actually have on human children will remain next to impossible.

The types of manipulations that are bound to remain foremost in many minds are biochemical/neuropharmacological ones. Will there eventually be medications, perhaps those that can enhance neuronal growth factors, that will help improve brain functions and maturation in predictable and beneficial ways? Probably, but the ethical issues in utilizing such agents, and hence, the difficulty in conducting efficacy studies in humans, are enormous and perhaps insurmountable. At the same time, we should recall that presently there are no formal legal safeguards against the use of drugs in children that have already been approved for adults. Such loopholes may eventually yield various troublesome long-term consequences. Indeed, one must already wonder to what extent iatrogenic developmental delays may be induced by the widespread long-term use of antiepileptic medications in young children that have experienced a few early seizures. Despite the promise of the many new biological interventions that are bound to come from basic neuroscience research, we must remain on our guard for many problems that could also emerge (e.g., Panksepp, 1998b).

CONCLUSION

The aim of this essay has been to highlight the importance of basic emotional issues for understanding the potential life trajectories of our children. This in no way is meant to diminish the importance of cognitive issues, but to encourage a new scientific and clinical openness to the many psychological processes that emotional systems enable. Obviously, the issues I have covered are important for children of all ages, not just infants. Because substantive scientific developments in this field are just beginning, it is premature to shut the door on any issues of scientific substance or potential clinical importance.

At the same time, we must remember how complex is the existing database for the effects of various early experiences on future developmental trajectories. Although the reality of such effects is becoming more widely accepted, the natural resilience of human children should never be underestimated. We need to clearly distinguish between myth and evidence in this field (Clark & Clark, 1976; Kagan, 1998; Rutter, 1972). We also need to distinguish between superficial adaptations, which can be cognitively promoted by remedial education and the deep existential and affective issues that individuals carry as internal baggage throughout their lives. Often such issues do not match up well, and emotional adjustments should be addressed in deep psychodynamic ways even when surface cognitive adjustments seem adequate. The thinking in this essay has been guided by the supposition that during early development there is no sustained line of cognitive activity without a sustained line of emotional arousal. The types of cognitive experiences and social feedback we provide for infants during their various forms of emotional arousal could coax them toward different internally experienced developmental paths even though there are few differences to be observed on external life measures.

If we believe in the causal efficacy of affect in the control of human and animal behaviors, it will be important for us to eventually specify what it means for the brain to experience affect and what consequences such processes have for behavior (my position on such issues has been summarized elsewhere; Panksepp, 1998a, 1998c). My take on the ontological issue is that affect emerges from the way the vertebrate brains were designed in evolution—with a core neural matrix for primordial SELF-representation that has the capacity to imbue the rest of psychological life with various forms of valenced arousal. It may be noteworthy than many prominent preclincial investigators of emotional processes do not agree with such conclusions; they believe that their subjects do *not* experience emotions (LeDoux, 1996; Rolls, 1999). They have difficulty envisioning how such processes could emerge from brain functions, and how such seemingly intangible psychological processes could control behaviors. My proposed solution to this “causal efficacy” issue is that affect provides organisms internally experienced value codes (i.e., they are automatic indicators of fitness decisions) that operate largely in the *long-term regulation of behavioral choices* rather than in the short-term control of eruptive emotional responses (Panksepp, Knutson, & Burgdorf, 2001).

In other words, felt affect is a way for organisms to project behavior patterns into the intermediate future after being confronted with various life-challenging stimuli. Affective states sensitize the organism to behave in certain categorical ways: SEEKING circuits help generate expectations and direct animals to the positive rewards to be had from the environment; RAGE circuits help counter irritation, frustrations, and other threats to one's freedom of action; FEAR circuits help protect animals from physical harm; LUST circuits promote sexual engagement; CARE circuits promote social devotion; PANIC circuits provide mammals with a sensitive emotional barometer to monitor the level of social support they are receiving; and PLAY circuits are important for learning various emotional and cognitive skills, including aspirations for social dominance and cooperation. Each of the basic emotional tendencies has its own characteristic feeling tone that promotes characteristic cognitive dispositions, but each of these aspects of mind need to be separately characterized. Consciously felt affective and informational/cognitive aspects of emotional processing may be very differently elaborated in the brain, and at present, it is most urgent to study the nature of affective consciousness more intensively to understand some of the major dynamics of infant development.

The types of research that needs to be initiated for us to become better informed about such matters and to head in optimal therapeutic/intervention directions is becoming ever clearer. We simply have to come to terms with the affective nature of various neural processes. I anticipate that such work will take away any lingering doubts we may have about the importance of emotions in the regulation of developmental trajectories. I might just note in passing that we have found the same drug to produce different behavioral outcomes when administered in two different affectively charged environments (Bekkedall, Panksepp, & Rossi, 1997). As we begin to navigate more confidently in this difficult area of basic knowledge, the payoffs, both scientific and cultural, are bound to be substantial.

Because we cannot ask most of the penetrating questions from manipulative work on our own species, we need to cultivate animal models that can provide answers to our most pressing concerns. Our rich understanding of evolutionary processes, basic psychobiological homologies within the brain and body, combined with the high probability that effective cross-species generalizations can be made in understanding the basic emotional systems of the brain, provide remarkable opportunities for the generation of useful new knowledge about infant developmental issues. In my mind, the key questions revolve around how various environments can modify the growth of the neuropsychological processes that emerge from these basic emotional circuits of the mammalian brain.

Unfortunately, within the present technocratic and highly positivistic neuroscientific era, it is remarkably difficult to harness the necessary resources to address such critical integrative issues. Partially, this is because we have just finished a century of scientific activity in which *experimental* psychology and neuroscience did not pay adequate attention to the emotional nature of humans or other animals. For a long time emotions were simply viewed as disruptive events, and only recently have they emerged as concepts that can help guide developmental studies. The psychoanalytic tradition of the past century had the intellectual sophistication to take us in very interesting scientific directions in the realm of emotion studies, but because of a lack of commitment to rigorous empirical evaluation and integration of concepts with neurobiological issues, it was abandoned in most scientific circles. Only recently are there signs of a healthy resurgence where basic emotional issues are tied to neuroscientific facts (see first issue of *Neuro-Psychoanalysis* highlighting "Freud's Theory of Affect" by Solms & Nersessian, 1999, and the succeeding commentaries).

Thus, among the most important question for developmental research in the twenty-first century we still have the following: How do we rear children so that they will be able to best use their emotional birthrights as positive living skills? How do we rear children who do not carry an abundance of negative emotional baggage deep within primary-process subconsciousness, ready to flare up and cause disruption in their own and others' social lives? How do we rear children who can utilize their emotions voluntarily for the betterment of the world? It is hard to imagine that anything can substitute for rich life experiences with *all* of the basic emotions, doled out within the safety of a secure and loving home base. Only when positive emotional concepts and values — a deep and natural emotional intelligence — begins to penetrate all layers of our social fabric, can we expect to have the best society of which we are capable.

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